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MORPHOLOGICAL CHARACTERIZATION AND EVALUATION OF SNAKE GOURD GENOTYPES FOR FRUIT YIELD, YIELD ATTRIBUTES AND OTHER CHARACTERS*

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Abstract

The experiment was conducted at the research field of Horticulture Department of Bangabandhu Sheikh Mujibur Raman Agricultural University (BSMRAU) during the period from March to June 2017 to characterize and evaluate the snake gourd genotypes morphologically. In the study, 55 snake gourd genotypes collected from Plant Genetic Resources Centre (PGRC) of Bangladesh Agricultural Research Institute (BARI), Genetics and Plant Breeding Department of BSMRAU, different seed companies and various parts of Bangladesh. The genotypes exhibited 67.3% cylindrical, 21.8% elliptical, 1.8% fusiform, 9.1% ovate shape fruit along with 56.4% green, 18.2% light green, 16.4% dark green and 9.0% white fruit. Seed colour with 38.2% was brown and 83.6% seed shape was elliptical. The fruit length varied from 12 to 54 cm while fruit diameter varied from 3.5 to 5.5 cm. Days to 1st female flower opening ranged between 44 and 62 days and nodes number on female flower initiation was between 12 and 26. Days to 1st fruit harvest varied from 54 to 72 days. The number of fruits/plants ranged from 8.33 to 27, whereas individual fruit weight varied from 90 to 325g. Fruit yield/plant ranged from 1.29 to 7.74 kg. Genotypes were TC01, TC03, TC04, TC05, TC07, TC08 and TC19 identified as early maturity. The genotypes differed significantly in most of the parameters and offer a good scope for selection of parent for crop improvement programme.

Keywords: Snake gourd, characterization, genotypes, yield components, plant breeding.

Introduction

Snake gourd (*Trichosanthes cucumerina* var. *anguina* L.) popularly known as ‘chichinga’ is a summer vegetable grown throughout Bangladesh. It is diploid (2n=2x = 22) and belongs to the family Cucurbitaceae. It is an annual creeper and day neutral type vegetable. It is highly cross-pollinated due to monoecism. Its immature fruit is consumed after cooking in tropical Asia including Bangladesh. It is rich in minerals and fiber. It is mainly grown in summer. Due to its day neutral habit it can be grown throughout the year except extreme cold months. Scarcity of vegetable prevails in the market during mid-March to mid-June and

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mid-September to mid-November. During these lean period only a few vegetables are available in the market and the quantity is very low in against the demand. The crop has the potential to fulfill the scarcity of vegetables during lean period. In the meantime, it has occupied prime place among the vegetables due to year round character, export potential and high nutritive value (Podder, 2010). Total production of snake gourd is 37,613 metric tons from an area of 7,496 hectares with an average yield of 5.02 tons per hectare (BBS, 2020) which is very low. There are many reasons for this low yield. Lack of high yielding variety i.e. non-availability of HYVs to the farmers/producers is one of the main reasons for this low yield. There are a good number of cultivars with wide range of variability in size, shape and colour of fruits available in different parts of the country (Rashid, 1993). Several open pollinated varieties of snake gourd have been released by different institutions, universities and seed companies namely ‘Jhum long’, ‘BARI Chichinga-1, ‘BU Chichinga -1’, ‘Porag 35’, ‘Taposi’, ‘Aunika 7’, ‘Radder’ and ‘Surma’. One hybrid variety called ‘Padma’ has been released by Lal Teer seed company. Hybrid varieties are also being imported from China by some seed companies, but these hybrids are not superior in quality. Besides, the snake gourd varieties released so far are inadequate in number to meet up the demand of the farmers. Therefore, to boost up the production of this vegetable there is no alternative way to developing high yielding open pollinated as well as good hybrid varieties. Morphological characterization is still used in crop improvement programme. It is relatively inexpensive and easy to carry out. Morphological characterization is a highly recommended preliminary step that should be made more in-depth biochemical or molecular studies are attempted. Genetic variability is a key component of successful breeding program for any crop species and a critical survey of genetic variability is extremely important before triggering an improvement program aimed at developing high yielding varieties (Rao *et al*., 1997; Haussmann *et al.*, 2004). There is a bright opportunity to research germplasm characterization, which is the prerequisite for the production of a high yielding snake gourd open pollinated or hybrid variety in Bangladesh (Ahmed *et al*., 2000). In relation, there is little knowledge available to delineate standardization for the horticultural and morphological characteristics. The research was therefore undertaken to characterize and to evaluate the germplasm in respect to yield and other morphological traits as well as to select the diverged germplasm for future plant breeding program.

Materials and Methods

The research work was conducted at the research field of Horticulture Department of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during the period from March to June, 2017. Fifty-five genotypes of snake gourd were collected from the Plant Genetic Resources

Centre, BARI, Genetics and Plant Breeding Department of BSMRAU, different seed companies and various parts of Bangladesh (Table 1). The experimental field soil was silty clay loam in texture with pH 6.20. It belongs to Madhupur tract to the Salna Series "Shallow Red Brown Terrace" soil (FAO, 1988 and Haider *et al.*, 1991). The soil sample from the experimental plot was collected from the depth of 15 cm and analyzed in the laboratory before initiation of the experiment. The nutrients contained in the experimental field were N (0.09 %), P (10.22 µg/g), K (0.07 meq/100 g soil), S (13.50 µg/g), Zn (0.90 µg/g) and B (0.28 µg/g). Minimum and maximum temperature during experimental period were 26.37^{0}C and 29.31^{0}C, respectively. The crop received 9.96 mm rainfall. Seeds were soaked in water for 24 hours to facilitate germination. Then, the seeds were sown in poly bags (10 cm × 12 cm). The growth medium of poly bags was prepared by mixing compost and soil at a ratio of 1 : 1. Seeds were sown on poly bags on 17 March, 2017. Seven days were required to germinate seeds. Seventeen days old seedlings were transplanted on 10 April, 2017, in the well prepared pit in an experimental plot and the pit size was 40 cm × 40 cm × 40 cm. The experiment was conducted in a Randomized Complete Block Design (RCBD) with three replications. A total of 165 (55 × 3) unit plots were prepared, each measuring 7.5 m × 1.5 m. Row and plant spacing were 1.5 m and 1.5 m, respectively. Fertilizers were applied @ 5000-100-24.5-84.0 -15.0-1.0-0.80 kg/ha of cowdung-N-P-K-S-Zn-B according to FRG (2012). The sources of N, P, K, S, Zn and B were urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum, zinc sulphate (monohydrate), boric acid (laboratory grade). The entire amount of cowdung, P, S, Zn, B and one-third of K were applied in the pit. The whole N and rest of K were applied into four equal installments at 7, 21, 35, 49 days after transplanting. Vertical trellises were made by using pieces of bamboo, GI wire and nylon net for supporting whole bearing plants. Necessary intercultural operations were done during the crop period for proper growth and development. Leaf miners, fruit flies and mites affected the crop plants. Insecticide of imidacloprid group (imitaf) @ 0.5 ml / l of water was sprayed to combat leaf miner and Vartimac @ 1.5 ml / l of water was applied against mites at a 7 day interval. To manage pesticide infestation, the liquid pesticide solutions were sprayed over the plants once per week for three to four times. Sex pheromone trap was set up at the fruiting stage in a densely 5 square meter / each trap to prevent fruit fly attack. Thirty three observations on qualitative (13) and quantitative (20) characters were recorded from each plot and genotype as per descriptor (AVRDC, 2015). Collected data were analyzed through STATISTIX 10 software and mean separation was done through Tukey’s Honesty Significant Different Test at 1% probability level.

Table 1. Source of collection and local names of 55 snake gourd genotypes

Acc. No.	Identity	Source
TC 01	BD-1607*	PGRC, BARI
TC 02	BD-1608	PGRC, BARI
TC 03	BD-1610	PGRC, BARI
TC 04	BD-1611	PGRC, BARI
TC 05	BD-1613	PGRC, BARI
TC 06	BD-1616	PGRC, BARI
TC 07	BD-1618	PGRC, BARI
TC 08	BD-1629	PGRC, BARI
TC 09	BD-1635	PGRC, BARI
TC 10	BD-1640	PGRC, BARI
TC 11	BD-1648	PGRC, BARI
TC 12	BD-1649	PGRC, BARI
TC 13	BD-1650	PGRC, BARI
TC 14	BD-1652	PGRC, BARI
TC 15	BD-1654	PGRC, BARI
TC 16	BD-1655	PGRC, BARI
TC 17	BD-1657	PGRC, BARI
TC 18	BD-1658	PGRC, BARI
TC 19	BD-1661	PGRC, BARI
TC 20	BD-1664	PGRC, BARI
TC 21	BD-1673	PGRC, BARI
TC 22	BD-4433	PGRC, BARI
TC 23	BD-4442	PGRC, BARI
TC 24	BARI Chicinga-1	HRC, BARI
TC 25	Pakunda (Local)	Kishorganj
TC 26	Julmon (Local)	Kishorganj
TC 27	China seed (Local)	Kishorganj
TC 28	China seed (Local)	Munshiganj
TC 029	Local seed	Manikganj
TC 30	Local seed	Manikganj
TC 31	Nayeem seed	Gazipur
TC 32	Metal seed (Porag 35)	Gazipur
TC 33	Banashree agro seed (Jumlong)	Siddique Bazar

Acc. No.	Identity	Source
TC 34	ACI seed (Taposi)	Siddique Bazar
TC 35	Sobuj seed	Siddique Bazar
TC 36	Local seed	Kustia
TC 37	Alamgir seed (Aunika 7)	Siddique Bazar
TC 38	Lalteer seed (Surma)	Siddique Bazar
TC 39	Local seed	Bikrampur
TC 40	Alauddin seed	Siddique Bazar
TC 41	Masud seed (Raddar)	Siddique Bazar
TC 42	650	Thailand
TC 43	SG001	BSMRAU
TC 44	SG004	BSMRAU
TC 45	SG006	BSMRAU
TC 46	SG010	BSMRAU
TC 47	SG018	BSMRAU
TC 48	SG025	BSMRAU
TC 49	SG026	BSMRAU
TC 50	Jhum snake gourd, mix	Gomoti, Matiranga
TC 51	Jhum snake gourd, small	Aladhon para, Khagrachori Sadar
TC 52	Jhum snake gourd, Ponkoj Tripura	Boropara, Khagrachori
TC 53	Jhum snake gourd, Oamra Marma	Boropara, Khagrachori
TC54	Jhum snake gourd, Johorlal Tripura	Thoiangopara, Khagrachori
TC 55	Jhum snake gourd, Kanonibala Tripura	Dighinala, Khagrachori

*Identities carrying ‘BD’ from 1 to 23were accessions number given by PGRC, BARI

Results and Discussion

A. Qualitative characters

A wide range of variation was observed among the genotypes for several qualitative characters (Tables 2, 3 & 7). All the genotypes had green cotyledon colour. Based on cotyledon size, the genotypes could be grouped into three distinct classes, namely small (7.3 %), medium (87.2 %) and large (5.5 %). Leaf blade shape was found round in all the genotypes (Table 2). Ara *et al*. (2013) classified leaf blade (lamina) type as blunt, pointed and medium pointed. Leaf blade lobbing was weak (43.6 %), intermediate (25.5 %) and strong (30.9 %). Repand type leaf blade margin (70.9%) was found dominant one followed by margin between serrate to dentate (29.1%). Leaf blade tip was obtuse (52.7%) and acute (47.3 %) (Table 2). Ekeke and Agogbua (2018) obtained similar type leaf blade margin and tip. Majority of the genotypes showed elongated ovary (40.0 %) followed by bottle shaped (34.5 %) and elliptic ovary (25.5%) (Table 2). Fruit colour at commercial stage was green (56.4 %) followed by light green (18.2 %), dark green (16.45% and white (9.0 %) (Tables 2 & 3). Similar findings with respect to fruit colour at commercial stage were also reported by Ara *et al*. (2013). Ranjit Chatterjee and Maitra (2014) reported that fruit skin colour varied from light green, green and dark green white stripes. Based on fruit shape, the genotypes could be grouped into four distinct morphological classes, namely cylindrical (67.3 %), elliptical (21.8 %), ovate (9.1 %) and fusiform (1.8 %%) (Tables 2 & 3). Ara *et al*. (2013) reported that majority of the genotypes had cylindrical fruit while evaluating 34 snake gourd genotypes. Ranjit Chatterjee and Maitra (2014) noted that fruit shape in snake gourd ranged from long spindle, elongated or cylindrical and tapering edge. All the genotypes had streaks on fruit (Tables 2 & 3). Six distinct types of seed colour were found viz., light brown (27.3%), light brown and brown at middle (1.8%), light brown and black (27.2%), light yellow and brown at middle (3.6%), brown (38.2%) and black and cream (1.8%) (Tables 2 & 7). Ekeke and Agobua (2018) obtained ash colour seed on an average in snake gourd. Based on seed shape, the genotypes could be grouped into three distinct classes, namely elliptical (83.6 %), round (1.8 %) and ovate (14.6 %), which indicated that most of the genotypes had elliptical seed. Cucurbit seeds vary in shape and structure that are used in family classification (Chakravarty and Hore, 1979). Skin of seed coat was fine (16.4%), intermediate (63.6%) and rough (20.0%).

Table 2. Frequency distribution (%) of qualitative characters of snake gourd genotypes

Characters	Class	Number of accession	Frequency (%)
1. Cotyledon color	Green	55	100.0
2. Cotyledon size	Small	4	7.3
	Medium	48	87.2
	Large	3	5.5
3. Leaf blade shape	Round	55	100.0
4. Leaf blade lobbing	Weak	24	43.6
	Intermediate	14	25.5
	Strong	17	30.9

Characters	Class	Number of accession	Frequency (%)
5. Leaf blade margin	Repand	39	70.9
	Between serate to dentate	16	29.1
6. Leaf blade tip	Obtuse	29	52.7
	Acute	26	47.3
7. Ovary shape	Elliptic	14	25.5
	Elongated	22	40.0
	Bottle shape	19	34.5
8. Fruit color at commercial	Green	31	56.4
	Light green	10	18.2
	Dark green	9	16.4
	White	5	9.0
9. Fruit shape	Cylindrical	37	67.3
	Elliptical	12	21.8
	Fusiform	1	1.8
	Ovate	5	9.1
10. Fruit streaks	Present	55	100.0
11. Seed color	Light brown	15	27.3
	Light brown and brown at middle	1	1.8
	Light brown and black	15	27.3
	Light yellow and brown at middle	2	3.6
	Brown	21	38.2
	Black and cream	1	1.8
12. Seed shape	Elliptical	46	83.6
	Round	1	1.8
	Ovate	8	14.6
13. Skin of seed coat	Fine	9	16.4
	Intermediate	35	63.6
	Rough	11	20.0

Table 3. Fruit qualitative characters of 55 snake gourd genotypes

Genotypes	Fruit color	Fruit shape	Fruit streaks
TC 01	Green	Cylindrical	Present (prominent)
TC 02	Light green	Cylindrical	Present (prominent)
TC 03	Green	Cylindrical	Present (prominent)
TC 04	Light green	Cylindrical	Present (prominent)
TC 05	Green	Cylindrical	Present (prominent)
TC 06	Green	Elliptical	Present (prominent)
TC 07	Green	Elliptical	Present (prominent)
TC 08	Green	Cylindrical	Present (prominent)
TC 09	Green	Elliptical	Present (prominent)
TC 10	Green	Cylindrical	Present (prominent)
TC 11	Light green	Cylindrical	Present (moderate)
TC 12	Light green	Cylindrical	Present (prominent)
TC 13	Green	Cylindrical	Present (prominent)
TC 14	Green	Cylindrical	Present (moderate)
TC 15	Green	Cylindrical	Present (prominent)
TC 16	Dark green	Elliptical	Present (moderate)
TC 17	Green	Cylindrical	Present (prominent)
TC 18	Green	Cylindrical	Present (prominent)
TC 19	Light green	Cylindrical	Present (moderate)
TC 20	Light green	Cylindrical	Present (moderate)
TC 21	Dark green	Elliptical	Present (prominent)
TC 22	Green	Cylindrical	Present (prominent)
TC 23	Green	Cylindrical	Present (prominent)
TC 24	Green	Cylindrical	Present (prominent)
TC 25	Light green	Cylindrical	Present (moderate)
TC 26	Green	Cylindrical	Present (prominent)
TC 27	Dark green	Elliptical	Present (prominent)
TC 28	Green	Cylindrical	Present (prominent)
TC 29	Dark green	Elliptical	Present (prominent)
TC 30	Dark green	Elliptical	Present (prominent)
TC 31	Dark green	Fusiform	Present (prominent)
TC 32	Dark green	Elliptical	Present (prominent)
TC 33	Green	Elliptical	Present (prominent)

Genotypes	Fruit color	Fruit shape	Fruit streaks
TC 34	Green	Cylindrical	Present (prominent)
TC 35	Light green	Cylindrical	Present (prominent)
TC 36	Green	Cylindrical	Present (prominent)
TC 37	Green	Cylindrical	Present (prominent)
TC 38	Green	Cylindrical	Present (prominent)
TC 39	Green	Cylindrical	Present (prominent)
TC 40	Dark green	Elliptical	Present (prominent)
TC 41	Light green	Ovate	Present (prominent)
TC 42	Light green	Cylindrical	Present (prominent)
TC 43	White	Cylindrical	Present (obscure)
TC 44	White	Cylindrical	Present (obscure)
TC 45	White	Cylindrical	Present (obscure)
TC 46	White	Cylindrical	Present (obscure)
TC 47	Green	Cylindrical	Present (prominent)
TC 48	Green	Cylindrical	Present (prominent)
TC 49	White	Cylindrical	Present (obscure)
TC 50	Green	Cylindrical	Present (prominent)
TC 51	Green	Elliptical	Present (moderate)
TC 52	Green	Ovate	Present (prominent)
TC 53	Dark green	Ovate	Present (prominent)
TC 54	Green	Ovate	Present (prominent)
TC 55	Green	Ovate	Present (prominent)

B. Quantitative characters

Plant characteristics

A wide range of variation was recorded for vine length with a mean of 4.6 m (Table 4). It ranged from 3.0 to 7.0 m. The longest vine was observed in TC 1 (7.0 m) followed by TC 3 (5.95 m), TC 5 (5.95 m), while the shortest vine was observed in TC 55 (3.0 m) followed by TC 48 (3.25 m). Significant variation in vine length of snake gourd was also reported by Ara *et al*. (2013), Ahsan *et al*. (2014) and Rahman and Ahmed (2014). Ara *et al*. (2013) found the vine length of snake gourd ranging from 1.08 to 1.80 m. Ahsan *et al*. (2014) noted the vine length of snake gourd in the range of 4.64 to 6.17 m whereas Rahman and Ahmed (2014) recorded the vine length with a ranged from 3.30 to 6.75 m in the same crop. The findings of the present study were close to those of Ahsan *et al*. (2014) and Rahman and Ahmed (2014) in terms of vine length. The results obtained by Ara *et al*. (2013) was lower than that of the present study because of the fact that Ara *et al*. (2013) recorded the vine length at first female flowering. Nodes on main vine varied from 24 to 39 with a mean of 32.62 (Table 4). The genotype TC 29 (39) had the highest number of nodes on the main vine followed by TC 41 (38), TC 01 (36), TC 07 (36), TC 16 (36), TC 27 (36), TC 42 (36) and TC 47 (36), whereas the genotype TC 44 (24) produced the lowest number of nodes/vine closely followed by TC 28 (29). Ara *et al*. (2013) reported that the highest variation range was observed in snake gourd as number of nodes /plant. Primary branch number/plant ranged from 3.5 to 8.0 with a mean of 5.5 (Table 4). The genotype TC 04 (8) produced maximum number of branches closely followed by TC 13 (7.5), TC 15 (7.5), TC 20 (7.5), whereas the genotype TC 35 (3.5), TC 39 (3.5), TC 50 (3.5) produced the least number of branches. Ahsan *et al.* (2014) reported the significant variation in the number of primary branches/plant with a range of 8.33 to 11.66 from the 7 parental lines of snake gourd genotypes.

Table 4. Plant growth characters of 55 snake gourd genotypes

Genotypes	Vine length (m)	Nodes on main vine	Primary branches/plant
TC 01	7.00a	36a-c	6.0de
TC 02	5.75b-d	31d-g	6.5cd
TC 03	5.95b	31d-g	5.0fg
TC 04	5.35b-h	31d-g	8.0a
TC 05	5.95b	35a-d	6.5cd
TC 06	5.30c-h	31d-g	7.0bc
TC 07	5.65b-d	36a-c	6.0de
TC 08	4.75h-m	34b-e	6.5cd
TC 09	4.90f-k	35a-d	6.0de
TC 10	4.00o-s	26hi	6.5cd
TC 11	5.00e-j	31d-g	6.0de
TC 12	5.75b-d	33c-f	7.0bc
TC 13	5.60b-e	35a-d	7.5ab
TC 14	5.50b-f	30e-h	6.5cd
TC 15	5.90bc	34b-e	7.5ab
TC 16	5.40b-g	36a-c	6.5cd
TC 17	5.20d-i	34b-e	7.0bc
TC 18	5.50b-f	32c-g	7.0bc
TC 19	4.90f-k	35a-d	6.5cd
TC 20	4.15m-s	30e-h	7.5ab
TC 21	4.10n-s	31d-g	6.5cd
TC 22	4.30k-q	32c-g	6.0de
TC 23	4.65i-n	35a-d	6.0de

Genotypes	Vine length (m)	Nodes on main vine	Primary branches/plant
TC 24	4.50j-o	34b-e	6.0de
TC 25	4.75h-m	32c-g	6.0de
TC 26	4.65i-n	36a-c	5.5ef
TC 27	4.85g-k	36a-c	7.0bc
TC 28	4.30k-q	29f-h	6.0de
TC 29	5.50b-f	39a	6.5cd
TC 30	4.25l-r	34b-e	5.5ef
TC 31	4.50j-o	34b-e	5.0fg
TC 32	4.25l-r	32c-g	4.5gh
TC 33	3.70q-t	31d-g	4.5gh
TC 34	4.50j-o	32c-g	4.5gh
TC 35	3.85p-t	31d-g	3.5i
TC 36	4.50j-o	33c-f	4.5gh
TC 37	3.62st	32c-g	4.0hi
TC 38	4.50j-o	32c-g	4.5gh
TC 39	3.90o-s	32c-g	3.5i
TC 40	4.00o-s	30e-h	4.0hi
TC 41	5.25d-i	38ab	4.0hi
TC 42	4.00o-s	35a-d	5.0fg
TC 43	4.75h-m	34b-e	5.0fg
TC 44	3.60s-u	24i	4.0hi
TC 45	4.25l-r	32c-g	6.0de
TC 46	3.90o-s	34b-e	4.5gh
TC 47	4.35k-p	36a-c	4.0hi
TC 48	3.25tu	28g-i	4.5gh
TC 49	3.75p-t	31d-g	4.5gh
TC 50	4.25l-r	32c-g	3.5i
TC 51	3.75p-t	31d-g	5.5ef
TC 52	4.00o-s	32c-g	5.0fg
TC 53	3.65r-t	31d-g	5.0fg
TC 54	4.50j-o	31d-g	4.0hi
TC 55	3.00u	32c-g	4.0hi
Mean	4.6	32.62	5.5
Range	3.0-7.0	24.0-39.0	3.5-8.0
CV (%)	3.87	3.83	3.91

NB: Figures in a column showing similar letters are not significantly different at 1% level of probability by Tukey’s Honestly Significance Difference Test

Flowering characteristics

Days to 1st male flower opening ranged from 39 to 59 days (Table 5). The earliest male flower opening was recorded in TC 05 (39 days) followed by TC 14 (41 days), TC 16 (41 days), TC 13 (42 days) and TC 15 (42 days). Ahsan *et al.* (2014) obtained days to 1st male flower opening in the range of 74.66 to 81.33 days among the 7 parental lines. Ara *et al*. (2013) reported that days to 1st male flowering ranged from 60 to 72 days among 34 snake gourd genotypes. Rajkumar *et al*. (2016) got days to 1st male flowering ranging from 18.38 to 46.50 days among 44 genotypes of snake gourd in India. A wide range of variation was observed in terms of days to 1st female flower opening which ranged from 44 to 62 days (Table 5). The earliest female flower opening was manifested in TC 03, TC 08 and TC 52 (44 days for each genotype) followed by TC 11 and TC 13 (45 days for each genotype). On the other hand, maximum days for female flower opening was recorded in TC 51 (62 days) followed by TC 06 (60 days). In snake gourd, the range of 1st female flower opening was 81.66 to 84.33 days that was reported by Ahsan *et al*. (2014). Ara *et al*. (2013) obtained days to 1st female flowering in the range of 65.0 to 75.0 days among 34 snake gourd genotypes. Significant variation was obtained in respect of node number at 1st male flower which ranged from 7 to 19 (Table 5). The lowest node number was obtained for node order for 1st male flower opening in TC 16 (7) followed by TC 5 (8), TC 11 (8) and TC 12 (8). Ahsan *et al.* (2014) reported that node number of 1st male flower opening ranged from 4.33 to 16.00 in 7 parental genotypes of snake gourd. Haque *et al*. (2014) noted node order of 1st male flowering ranging from 9.00 to 14.00 while evaluating of snake gourd genotypes. Node number of 1st female flower opening ranged from 12 to 26 and statistically significant variation was observed in snake gourd genotypes (Table 5). The lowest node number to 1st female flower initiation was recorded in TC 03 (12) followed by TC 16 (14), TC 07 (15), TC 08 (15), TC 11 (15), TC 12 (15), TC 13 (15), TC 21 (15), TC 22 (15), TC 53 (15), TC 55 (15). Ahsan *et al.* (2014) recorded the node number of 1st female flower anthesis in the range of 18.33 to 22.66 among 7 parental lines of snake gourd. Joseph (1978) obtained nodes for initiation of female flower in snake gourd in the range of 15.00 to 23.44. Deepa Devi *et al*. (2016) reported that node number at 1st female flowering ranged from 15.61 to 24.87 in 13 parental lines of snake gourd in India. Substantial variation among the snake gourd genotypes was observed for ovary length (Table 5). Maximum ovary length was found in the TC 04 (3.5 cm) followed by TC 22 (3.0 cm) and TC 47 (3 cm). Significant variability among the snake gourd genotypes was also observed for ovary diameter (Table 5). Ovary diameter was noticed maximum in the TC 22 (0.8 cm) followed by TC 04 (0.75 cm).

Table 5. Flowering characteristics of 55 snake gourd genotypes

Genotypes	Days to 1st flower open		Nodes on 1st flower initiation		Ovary of female flowers	
	Male	Female	Male	Female	Length (cm)	Diameter (cm)
TC 01	46d-h	47f-h	10ij	18g-i	2.00gh	0.50d
TC 02	44f-i	46gh	14ef	19f-h	2.00gh	0.50d
TC 03	43f-i	44h	11hi	12l	2.75b-d	0.50d
TC 04	46d-h	47f-h	13fg	16i-k	3.50a	0.75ab
TC 05	39i	46gh	8jk	22c-e	2.50de	0.50d
TC 06	58ab	60ab	12gh	24a-c	2.00gh	0.40e
TC 07	52b-d	47f-h	10ij	15jk	2.00gh	0.50d
TC 08	43f-i	44h	9jk	15jk	2.50de	0.50d
TC 09	51c-e	47f-h	13fg	17h-j	2.50de	0.50d
TC 10	43f-i	45h	9jk	19f-h	2.75b-d	0.50d
TC 11	44f-i	45h	8jk	15jk	2.50de	0.50d
TC 12	43f-i	45h	8jk	15jk	2.75b-d	0.50d
TC 13	42g-i	45h	10ij	15jk	2.00gh	0.50d
TC 14	41hi	55b-e	17bc	20e-g	2.00gh	0.50d
TC 15	42g-i	49e-h	10ij	16i-k	2.00gh	0.50d
TC 16	41hi	47f-h	7l	14kl	2.50de	0.60c
TC 17	46d-h	48f-h	15de	16i-k	2.00gh	0.50d
TC 18	46d-h	52d-g	15de	19f-h	2.50de	0.50d
TC 19	45e-i	46gh	17bc	22c-e	2.00gh	0.50d
TC 20	47c-h	53c-f	16cd	19f-h	2.20fg	0.60c
TC 21	46d-h	48f-h	12gh	15jk	2.50de	0.70b
TC 22	46d-h	55b-e	10ij	15jk	3.00b	0.80a
TC 23	48c-g	48f-h	12gh	16i-k	2.50de	0.50d
TC 24	46d-h	47f-h	13fg	19f-h	2.00gh	0.50d
TC 25	44f-i	49e-h	9jk	16i-k	2.00gh	0.50d
TC 26	51c-e	55b-e	14ef	21d-f	2.00gh	0.50d
TC 27	46d-h	49e-h	18ab	20e-g	2.00gh	0.50d
TC 28	47c-h	48f-h	13fg	18g-i	2.00gh	0.50d
TC 29	48c-g	49e-h	15de	21d-f	2.00gh	0.50d

Genotypes	Days to 1st flower open		Nodes on 1st flower initiation		Ovary of female flowers	
	Male	Female	Male	Female	Length (cm)	Diameter (cm)
TC 30	51c-e	59a-c	16cd	20e-g	2.00gh	0.50d
TC 31	48c-g	48f-h	17bc	16i-k	1.50j	0.50d
TC 32	48c-g	56a-d	12gh	21d-f	1.50j	0.50d
TC 33	48c-g	49e-h	19a	18g-i	2.50de	0.50d
TC 34	46d-h	55b-e	15de	26a	2.80bc	0.60c
TC 35	46d-h	46gh	17bc	22c-e	2.00gh	0.50d
TC 36	46d-h	47f-h	15de	22c-e	2.00gh	0.50d
TC 37	47c-h	47f-h	14ef	17h-j	2.50de	0.60c
TC 38	49c-f	50d-h	15de	20e-g	1.60j	0.40e
TC 39	49c-f	49e-h	15de	20e-g	2.00gh	0.50d
TC 40	47c-h	48f-h	16cd	19f-h	2.30ef	0.50d
TC 41	53a-c	59a-c	15de	18g-i	1.90hi	0.50d
TC 42	48c-g	49e-h	17bc	20e-g	2.70cd	0.70b
TC 43	47c-h	50d-h	13fg	23b-d	2.00gh	0.60c
TC 44	46d-h	49e-h	11hi	17h-j	2.50de	0.50d
TC 45	46d-h	50d-h	14ef	25ab	1.70ij	0.50d
TC 46	45e-i	50d-h	11hi	18g-i	3.00b	0.50d
TC 47	47c-h	48f-h	13fg	21d-f	3.00b	0.70b
TC 48	47c-h	52d-g	13fg	24a-c	2.00gh	0.50d
TC 49	45e-i	48f-h	11hi	21d-f	2.20fg	0.60c
TC 50	46d-h	47f-h	14ef	16i-k	1.50j	0.50d
TC 51	59a	62a	18ab	23b-d	1.50j	0.50d
TC 52	45e-i	44h	16cd	19f-h	1.50j	0.50d
TC 53	48c-g	47f-h	12gh	15jk	1.75h-j	0.50d
TC 54	48c-g	49e-h	13fg	17h-j	2.00gh	0.50d
TC 55	48c-g	49e-h	10ij	15jk	1.70ij	0.50d
Mean	46.67	49.33	13.10	18.58	2.19	0.53
Range	39.0-59.0	44.0-62.0	7.0-19.0	12.0-26.0	1.5-3.5	0.40-0.80
CV (%)	3.84	3.84	3.91	3.87	3.90	3.88

NB: Figures in a column showing similar letters are not significantly different at 1% level of probability by Tukey's Honestly Significance Difference Test

Fruit characteristics

A substantial variation was found among the genotypes in days to 1st fruit harvest at marketable stage and it ranged from 54 to 75 days (Table 6). Minimum time was required for 1st fruit harvest of the genotype TC 05 (54 days) followed by TC 01, TC 03, TC 04, TC 07, TC 08, TC 19, TC 23, TC 35, TC 37, TC 42 and TC 46 (57 days for each genotype). Maximum time was required for 1st fruit harvesting of the genotypes TC 30, TC 34, TC 41 and TC 45 (75 days for each genotype) closely followed by TC 15, TC 20, TC 22, TC 25, TC 26, TC 27, TC 32, TC 33, TC 36, TC 38, TC 40, TC 43, Tc 47, TC 48 and TC 49 (72 days for each genotype). Ara *et al.* (2013) reported that snake gourd genotypes differed significantly with respect to 1st harvest ranging from 77.0-90.0 days. The result of the present study was lower than the result reported by Ara *et al*. (2013) in respect of days to 1st fruit harvest. Fruit length ranged from 12 to 54 cm (Table 6). Maximum fruit length was observed in TC 47 (54 cm) followed by TC 42 (50 cm) and TC 01 (48 cm) whereas the lowest fruit length was registered in TC 55 (12 cm) followed by TC 53 (17 cm), TC 54 (18 cm) and TC 21 (19 cm). In snake gourd, Ara *et al.* (2013) obtained fruit length in the range of 25.33 to 45.33 cm. Fruit diameter varied from 3.5 to 5.5 cm (Table 6). In addition, the highest diameter of the fruit was recorded in TC 51 (5.5 cm) followed by TC 13, TC 16, TC 31 and TC 53 (4.8 cm for each genotype), while the lowest in TC 35 (3.5 cm) closely followed by TC 06 (3.6 cm), TC 15 (3.6 cm), TC 34 (3.6 cm) and TC 20 (3.7 cm). Ahsan *et al.* (2014) recorded fruit diameter in the range of 2.62 to 5.09 cm. Rahman and Ahmed (2014) reported the range of fruit diameter from 2.60 to 6.14 cm. Number of fruits /plant ranged from 8.33 to 27.0 (Table 6). Number of fruits /plant was noted maximum in TC 05 (27.0) followed by TC 07 (25.0) and then followed by TC 01 (24.33), TC 02 (24.33), TC 46 (24) and TC 53 (24.67) while its value was found minimum in TC 48 (9.0), TC 06 (9.33) and TC 43 (9.33). Ahsan *et al.* (2014) reported significant variations for the number of fruits /plant among the parents ranging from13.00 to 32.33 fruits/ plant. Rajkumar *et al*. (2016) obtained the number of fruits /plant in the range of 7.00 to 27.50 fruits /plant, while Rahman and Ahmed (2014) obtained from 4.50 to 23.50. Ara *et al*. (2013) obtained 16.00 to 45.60 number of fruits /plant in 34 snake gourd genotypes. The results of the present study are very close to the results of most of the reports. However, the findings about number of fruits /plant reported by Ara *et al*. (2013) were higher than the findings of the present study. Individual fruit weight varied from 90 to 325 g (Table 6). The genotype TC 18 recorded maximum individual fruit weight 325 g which was identical to those of TC 01 (310 g), TC 04 (318 g) and TC12 (300 g) and the lowest single fruit weight was found in TC 55 (90 g) followed by TC 54 (100 g), TC 53 (110 g), TC 50 (148 g) and TC 34 (148 g). Ahsan *et al.* (2014) obtained individual fruit weight in the range of 101.89 to 159.45 g from 7 parental lines. Rahman and Ahmed (2014) reported that marked variation was observed in terms of individual fruit which ranged from 81.34 to 441.81 g. Maximum yield /plant was recorded in the genotype TC 04 (7.74 kg) closely followed by TC 01 (7.54 kg), TC 02 (7.06 kg) and TC 05 (7.28 kg) (Table 6) and the lowest yield /plant was derived from the genotype TC 55 (1.29 kg) followed by TC 54 (1.50 kg), TC 06 (1.68 kg), TC 43 (1.62 kg), TC 48 (1.80 kg), TC 50 (1.73 kg) and TC 51 (1.79 kg). In snake gourd, Ara *et al.* (2013) reported that weight of fruits /plant differed significantly among the 34 genotypes and this character ranged from 3.27 to 9.15 kg/plant. Rahman and Ahmed (2014) also got wide variation in fruit yield /plant ranging from 0.30 to 6.01 kg among the 32 snake gourd genotypes, while Rajkumar *et al.* (2016) obtained fruit yield /plant in the range of 3.06 to 10.49 kg from the 44 snake gourd genotypes in India. Ahsan *et al.* (2014) reported the range of yield /plant was 1.60 to 4.76 kg. The findings of the present study corroborated the result of Rahman and Ahmed (2014) and Ara *et al.* (2013).

Table 6. Fruit characteristics of 55 snake gourd genotypes

Genotypes	Days to harvest	Fruit length (cm)	Fruit diameter (cm)	Fruits/plant	Individual fruit weight (g)	Fruit yield/ plant (kg)
TC 01	57cd	48b	4.4b-e	24.33b-d	310ab	7.54ab
TC 02	68ab	40c-e	4.2c-f	24.33b-d	290b-e	7.06ab
TC 03	57cd	25l-o	4.5b-e	17.00j-n	187s-x	3.18o-t
TC 04	57cd	40c-e	4.5b-e	24.33b-d	318ab	7.74a
TC 05	54d	40c-e	4.4b-e	27.00a	270d-h	7.28ab
TC 06	68ab	27k-m	3.6gh	9.33vw	180u-y	1.68z
TC 07	57cd	27k-m	4.3b-e	25.00ab	240i-n	6.01cd
TC 08	57cd	28j-m	4.3b-e	19.67g-i	208u-o	4.09h-n
TC 09	68ab	29i-l	4.1d-g	15.33m-r	197r-w	3.02o-v
TC 10	68ab	29i-l	4.3b-e	20.42e-h	210o-t	4.28g-l
TC 11	68ab	41cd	4.4b-e	22.33c-f	298a-d	6.66bc
TC 12	72ab	40c-e	4.0f-h	20.33e-h	201p-v	4.09h-n
TC 13	68ab	35fg	4.8b	18.00h-l	300a-c	5.40de
TC 14	68ab	28j-m	4.4b-e	20.00f-i	151y-a	3.02o-v
TC 15	72ab	29i-l	3.6gh	22.00d-g	170w-z	3.74j-o
TC 16	68ab	27k-m	4.8b	22.67b-e	231j-o	5.24d-f
TC 17	68ab	30h-k	4.2c-f	17.00j-n	217l-r	3.69k-p
TC 18	68ab	43c	4.5b-e	15.67l-r	325a	5.09e-g
TC 19	57cd	29i-l	4.5b-e	15.33m-r	277c-f	4.25g-l
TC 20	72ab	40c-e	3.7f-h	15.33m-r	210o-t	3.22n-t
TC 21	68ab	19q-r	4.2c-f	16.00k-q	132z	2.11w-b
TC 22	72ab	40c-e	4.0f-h	12.33s-u	230k-p	2.83p-w
TC 23	57cd	42c	4.2c-f	11.67t-u	260f-j	3.04o-v
TC 24	72ab	43c	4.4b-e	19.00h-j	250f-k	4.75e-i

Genotypes	Days to harvest	Fruit length (cm)	Fruit diameter (cm)	Fruits/plant	Individual fruit weight (g)	Fruit yield/ plant (kg)
TC 25	72ab	33f-i	4.4b-e	10.00u-w	213n-t	2.13w-b
TC 26	72ab	26k-n	4.3b-e	14.00p-t	185t-x	2.59s-y
TC 27	72ab	22n-q	4.6b-d	10.00u-w	229k-q	2.29u-a
TC 28	68ab	27k-m	4.4b-e	17.67i-m	177v-z	3.13o-u
TC 29	68ab	34f-h	4.4b-e	13.67q-t	262e-i	3.58l-q
TC 30	75a	29i-l	4.2c-f	14.67n-s	243g-m	3.57l-q
TC 31	68ab	20p-r	4.8b	14.33o-s	230k-p	3.30m-t
TC 32	72ab	29i-l	4.7bc	15.33m-r	272c-g	4.17h-m
TC 33	72ab	36e-g	4.2c-f	18.33h-k	250f-k	4.59e-j
TC 34	75a	24m-p	3.6gh	14.00p-t	160x-a	2.24w-a
TC 35	57cd	29i-l	3.5h	14.33o-s	148z	2.12w-b
TC 36	72ab	28j-m	4.6b-d	17.00j-n	210o-t	3.56l-r
TC 37	57cd	32g-j	4.5b-e	16.67j-o	255f-k	4.25g-l
TC 38	72ab	30h-k	4.4b-e	17.67i-m	232j-o	4.10h-n
TC 39	68ab	40c-e	4.1d-g	18.33h-k	245g-l	4.49f-k
TC 40	72ab	26k-n	4.6b-d	16.33k-p	255f-k	4.16h-m
TC 41	75a	20p-r	4.6b-d	19.67g-i	165x-z	3.24n-t
TC 42	57cd	50ab	4.5b-e	16.67j-o	295b-d	4.92e-h
TC 43	72ab	29i-l	4.0f-h	9.33vw	175v-z	1.62z
TC 44	68ab	28j-m	4.5b-e	20.00f-i	158x-a	3.15o-u
TC 45	75a	34f-h	4.0f-h	10.00u-w	242h-n	2.42t-z
TC 46	57cd	37d-f	4.2c-f	24.00b-d	200q-v	4.79e-h
TC 47	72ab	32g-j	4.4b-e	13.67q-t	245g-l	3.35m-s
TC 48	72ab	30h-k	4.3b-e	9.00w	200q-v	1.80x-b
TC 49	72ab	54a	4.0f-h	13.33r-t	290b-e	3.87i-o
TC 50	69ab	21o-r	4.6b-d	11.67t-u	148z	1.73y-b
TC 51	69ab	25l-o	5.5a	8.33w	215m-s	1.79x-b
TC 52	69ab	21o-r	4.0f-h	16.00k-q	167x-z	2.67r-x
TC 53	69ab	17r	4.8b	24.67a-c	110z	2.77q-w
TC 54	65bc	18q-r	4.0f-h	15.00n-r	100z	1.50z
TC 55	69ab	12s	4.3b-e	14.33o-s	90z	1.29z
Mean	67.33	31.13	4.31	16.77	218.69	3.71
Range	54.0-75.0	12.0-54.0	3.5-5.5	8.3-27.0	132-325	1.68-7.74
CV (%)	3.86	3.97	3.85	4.32	3.96	7.0

NB: Figures in a column showing similar letters are not significantly different at 1% level of probability by Tukey’s Honestly Significance Difference Test.

Seed characteristics

Seed length was maximum in TC 30, TC 38 and TC 46 (18.8 mm in each genotype) closely followed by TC 25 (18.0 mm), TC 40 (18.3 mm). Minimum value was recorded in TC 17 (10.3 mm). Maximum seed width was recorded in TC 06 (12.3 mm) closely followed by TC 28 and TC 41 (12.0 mm in each genotype) as well as minimum seed width in TC 43 (9.3mm). Seed length and width ranged from 10.3 to 18.8 mm and 9.3 to 12.3 mm, respectively (Table 7). Ekeke and Agogbua (2018) found an average seed length and width of 13.25 mm and 6.82 mm respectively in snake gourd. A little variation was found in seed thickness which ranged from 5.0 mm to 6.2 mm. Ekeke and Agogbua (2018) found an average seed thickness of 5.5 mm in snake gourd. Significant variations were found with respect to number of seeds /fruit and 100-seed weight (Table 7). These two seed characters ranged accordingly from 12 to 93 and from 16 to 55 g.

Table 7. Seed characteristics of 55 snake gourd genotypes

Genotypes	Seed color	Seed shape	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	100-seed weight (g)	Seeds / fruit
TC 01	11	Elliptical	16.5b-f	10.0d-g	5.5a-d	30gh	64f-i
TC 02	5	Elliptical	17.3a-e	11.0a-e	6.0ab	33fg	36r-u
TC 03	9	Elliptical	17.3a-e	9.8e-g	6.0ab	28hi	52k-m
TC 04	5	Elliptical	17.5a-d	10.0d-g	6.0ab	28hi	67e-h
TC 05	1	Elliptical	17.3a-e	11.0a-e	5.3b-d	30gh	54j-l
TC 06	9	Elliptical	17.8a-d	12.3a	6.0ab	28hi	43n-r
TC 07	9	Elliptical	17.0a-f	10.3d-g	5.0d	28hi	71c-f
TC 08	9	Elliptical	17.8a-d	10.2d-g	5.3b-d	24jk	77bc
TC 09	9	Elliptical	17.2a-e	11.8a-c	6.0ab	30gh	63g-i
TC 10	1	Elliptical	17.0a-f	10.5c-g	6.0ab	32fg	68e-g
TC 11	9	Elliptical	17.3a-e	11.0a-e	5.8a-c	34f	93a
TC 12	9	Elliptical	17.0a-f	11.0a-e	6.0ab	30gh	45m-q
TC 13	9	Ovate	16.3b-f	11.0a-e	6.0ab	28hi	60h-j
TC 14	1	Elliptical	17.8a-d	11.2a-d	5.8a-c	24jk	58i-k
TC 15	1	Ovate	17.0a-f	11.8a-c	6.0ab	26ij	69d-g
TC 16	1	Elliptical	17.8a-d	11.3a-d	5.0d	30gh	63g-i
TC 17	1	Elliptical	10.3g	10.0d-g	5.0d	22kl	50l-n
TC 18	9	Elliptical	16.8a-f	11.0a-e	5.8a-c	30gh	50l-n

Genotypes	Seed color	Seed shape	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	100-seed weight (g)	Seeds / fruit
TC 19	5	Elliptical	17.0a-f	11.2a-d	6.0ab	30gh	60h-j
TC 20	5	Elliptical	18.0a-c	11.0a-e	6.0ab	35ef	40p-s
TC 21	9	Ovate	17.0a-f	11.3a-d	6.0ab	32fg	63g-i
TC 22	5	Elliptical	16.5b-f	9.5f-g	5.5a-d	26ij	74b-e
TC 23	9	Elliptical	16.3b-f	10.5c-g	6.0ab	30gh	81b
TC 24	9	Elliptical	17.0a-f	12.0ab	6.0ab	40cd	28vw
TC 25	5	Elliptical	18.0a-c	11.3a-d	5.0d	32fg	30u-w
TC 26	5	Elliptical	17.0a-f	10.0d-g	5.0d	30gh	54j-l
TC 27	1	Ovate	16.0c-f	11.2a-d	5.4b-d	26ij	70c-g
TC 28	5	Ovate	17.0a-f	12.0ab	6.0ab	30gh	63g-i
TC 29	9	Elliptical	16.0c-f	9.8e-g	5.0d	30gh	76b-d
TC 30	9	Elliptical	18.8a	11.0a-e	6.0ab	34f	60h-j
TC 31	1	Elliptical	15.3ef	10.0d-g	5.0d	22kl	60h-j
TC 32	9	Round	15.0f	11.0a-e	6.2a	20l	12x
TC 33	1	Elliptical	17.0a-f	11.0a-e	5.5a-d	30gh	48l-o
TC 34	9	Elliptical	17.0a-f	10.8b-f	5.3b-d	33fg	40p-s
TC 35	1	Elliptical	17.0a-f	10.3d-g	5.3b-d	55a	43n-r
TC 36	5	Elliptical	17.0a-f	10.0d-g	5.5a-d	42bc	64f-i
TC 37	7	Ovate	15.0f	11.0a-e	5.0d	24jk	50l-n
TC 38	9	Elliptical	18.8a	11.0a-e	6.0ab	34f	46m-p
TC 39	5	Elliptical	16.0c-f	10.0d-g	5.3b-d	38de	43n-r
TC 40	9	Elliptical	18.3ab	11.3a-d	6.0ab	44b	25w
TC 41	3	Elliptical	17.8a-d	12.0ab	5.8a-c	30gh	58i-k
TC 42	9	Elliptical	16.8a-f	10.3d-g	5.5a-d	30gh	58i-k
TC 43	1	Elliptical	16.0c-f	9.3g	4.8d	16m	34s-v
TC 44	1	Elliptical	16.3b-f	10.3d-g	5.0d	30gh	42o-r
TC 45	5	Elliptical	16.0c-f	10.0d-g	5.0d	35ef	38q-t
TC 46	5	Elliptical	18.8a	11.8a-c	6.0ab	30gh	49l-o
TC 47	7	Elliptical	15.8d-f	9.7e-g	5.2cd	24jk	42o-r

Genotypes	Seed color	Seed shape	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	100-seed weight (g)	Seeds / fruit
TC 48	5	Elliptical	16.0c-f	11.0a-e	5.0d	32fg	32t-w
TC 49	5	Ovate	17.3a-e	11.0a-e	6.0ab	30gh	26w
TC 50	9	Ovate	17.3a-e	10.8b-f	5.0d	30gh	34s-v
TC 51	5	Elliptical	15.0f	10.3d-g	5.0d	24jk	32t-w
TC 52	9	Elliptical	15.3ef	9.3g	5.0d	26ij	63g-i
TC 53	1	Elliptical	16.8a-f	9.8e-g	6.0ab	26ij	64f-i
TC 54	1	Elliptical	15.0f	10.0d-g	5.0d	24jk	79b
TC 55	1	Elliptical	16.4b-f	9.8e-g	5.0d	24jk	46m-p
Mean	-	-	16.74	10.69	5.54	29.87	52.91
Range	-	-	10.3-18.8	9.3-12.3	5.0-6.2	16-55	12-93
CV (%)	-	-	3.82	3.83	3.84	3.90	4.02

NB: (-) Not analyzed; 1= Light brown, 3= Light brown and brown at middle, 5= Light brown and black, 7=Light yellow and brown at middle, 9= Brown, 11= Black and cream.

Figures in a column showing similar letters are not significantly different at 1% level of probability by Tukey's Honestly Significance Difference Test

Maximum seed number was observed in TC 11 (93) followed by TC 23 (81) and TC 54 (79) and minimum seed number was manifested in TC 32 (12) followed by TC 40 (25) and TC 49 (26). Kumar *et al.* (2013) reported that substantial variation was observed among the 20 snake gourd genotypes for 100-seed weight and it ranged from 18 to 55 g. Maximum amount of a 100-seed weight was observed in TC 35 (55 g) followed by TC 40 (44 g) and TC 36 (42 g). Minimum 100-seed weight was recorded in TC 43 (16 g) followed by TC 32 (20 g), TC 17 (22 g) and TC 31 (22 g). This trait ranged from 20.0 g to 41.0 g in snake gourd (Varghese, 1991). Rahman and Ahmed (2014) obtained 100-seed weight in the range of 24.0 to 38.0 g.

Conclusion

Based on the above results and discussion, most of the qualitative characters showed distinct variation and maximum variation was observed in fruit colour and fruit shape. Significant variation was also observed in quantitative characters and fruit yield per plant. The promising genotypes identified as TC 01, TC 02, TC 05, TC 10, TC 18, TC 22, TC 24, TC 33, TC 36, TC 40, TC 41, TC 42, TC 44, TC 46 and TC 53 have potential to be used in future breeding program for getting productive and desirable traits. Moreover, the variability observed in the present study could be used in the snake gourd improvement programme.

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INCIDENCE OF APHID ON DIFFERENT BRINJAL GERMPLASM RELATED TO ABIOTIC AND BIOTIC FACTORS

F. YASMIN[1], M. R. AMIN[2], M. A. H. SWAPON[3] AND M. M. HOSSAIN[4]

Abstract

The study was conducted with BD-7320, BD-7328, BD-9952, BD-10154, BD-10158, BARI Begun-1, BARIBegun-4, BARIBegun-5, BARIBegun-6, BARIBegun-7, BARIBegun-8 and BARIBegun-9 germplasms of brinjal with a view to understanding the effect of temperature, relative humidity, rainfall and predators on the incidence of aphid during September 2018 to March 2019. Aphid incidence and infestation started from the last week of November and the highest incidence was recorded during 2nd week of January on BD-10154.At that week, aphid showed lower number of incidence on BARI Begun-5, BARI Begun-6, BARI Begun-8 and BARI Begun-9. The highest infestation of aphid was observed on BARI Begun-5 during 2nd week of March, when the lowest infestation was found on BD-9952. Maximum and minimum temperatures showed significant positive correlation, relative humidity (RH) and rainfall revealed non-significant correlation with aphid incidence. Aphid abundance showed highly significant positive correlation with the abundance of predators on all the tested germplasms.

Keywords: *Solanum melongena, Myzus persicae,* predator, meteorological parameters.

Introduction

Brinjal *Solanum melongena* L. is an annual vegetable which belongs to the family Solanaceae. In Bangladesh, over 50.4 thousand ha land is devoted to brinjal cultivation annually and production is 340.2 thousand metric tons (BBS, 2016). Aphid is one of the most harmful threats to brinjal and their infestation caused significant reduction of yield (Miller *et al.*, 2009). The nymphs and adults of aphid suck sap from the leaves and tender shoots, and the infested plants become weak, pale, stunted, and reduced fruit size and yield as high as 25-40% (Ghosh *et al*., 2004).

Germplasms of plant species vary in their morphological traits like canopy area, number of branch, number of hairs and trichomes per unit area of leaf, color of stem, leaf, flower and fruit etc. These physical characteristics influence on the abundance, infestation and foraging behavior of herbivore insects as well as the population of natural enemies. Afroz *et al*. (2019) observed fluctuations of the population of epilachna beetle, red pumpkin beetle and fruit fly on different

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germplasms of sweet gourd. Growth stages of the host plant also affect pest population abundance and dynamics. Some plants show susceptibility to a specific herbivore insect at their seedling stage, some show susceptibility at their juvenile stage (flowering and fruiting), and some are susceptible from seedling to harvesting.

Meteorological parameters play pivotal roles in the various growth and development stages of crop, and influence on the reproduction, behavior, abundance and infestation of phytophagous insects. The daily mean temperature had significant negative, light intensity had insignificant negative and relative humidity had insignificant positive correlation with the abundance of aphid on mustard (Mandal *et al.*, 2018).Amin *et al*.(2017) reported insignificant effect of temperature, relative humidity and rainfall on the incidence of aphid on CB1, CB3, CB5, CB8 and CB12 varieties of cotton at Gazipur in Bangladesh.

Predator insects are one of the important group of biotic components affecting pest population dynamics in the agricultural crop field. Among the predators, lady bird beetle and spider are reported as the highly effective natural enemies of aphid (Ali and Rizvi,2009; Mathirajan and Regupathy, 2003; Ghawami, 2008).

Resistant and tolerant germplasms are the basic component of Integrated Pest Management (IPM). For selecting a germplasm against any insect pest, it is utmost necessary to know the seasonal incidence of the pest on that germplasm. It is also important to find out relationship between pest population with meteorological parameters and abundant predators. With this point in view, the present study was carried out to know the incidence and infestation of aphid on twelve germplasms of brinjal, and to find outout correlation between the abundance of aphid with meteorological parameters and predators like lady bird beetle and spider.

Materials and Methods

Study site and condition

The study was conducted during September 2018 to March 2019 in the field and laboratory of the Department of Entomology, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh. The area is located in the middle of Bangladesh at 25°25′ N and 89°5′ E with 34 m altitude above sea level. The area is characterized by a well-defined dry season (February to May), rainy season (June to September) and short winter (October to January) (Amin *et al*., 2015).

Cultivation of brinjal

Twelve germplasms of brinjal were used as experimental material. Among them BARI Begun- 1, BARI Begun- 4, BARI Begun- 5, BARI Begun- 6, BARI Begun- 7, BARI Begun- 8 and BARI Begun- 9 were Bangladesh Agricultural

Research Institute (BARI), Gazipur released variety and rest five genotypes namely BD- 7320, BD- 7328, BD- 9952, BD- 10154 and BD-10158were collected from Plant Genetic Resource Centre, BARI. Each germplasm was cultivated in 3.0 m × 3.0 m plot following randomized complete block design with three replications. The spacing between block to block and plot to plot was 1.0 m and 1.0 m, respectively. Seeds were sown on 5thOctober 2018 in seedbed and 30 days old seedlings were transplanted to the field on 4th November, 2018.Fertilizers were applied according to the fertilizer recommendation guide (FRG, 2012). All the intercultural operations except insect control were adopted whenever necessary.

Data collection and analysis

To observe the incidence and infestation of aphid, field inspection was done weekly. For collecting data, five plants were randomly selected for each germplasm. Number of aphids prevailed on the top, middle and bottom leaves of the selected plants were recorded using hand lens. Number of healthy leaves and number of infested leaves of the selected plants were also counted and infestation level was calculated in percentage. Numbers of lady bird beetle and spider existed on the selected plants were counted through visual observation. Weather data was collected from the weather station of BSMRAU, Gazipur. Simple correlation using IBM SPSS 20.0 was worked out between the incidence of aphid on different germplasms with meteorological parameters, and abundance of predators.

Results and Discussion

Incidence of aphid on the brinjal germplasms showed fluctuations throughout the study (Figure 1). Aphid showed their incidence from the last week of November but data were collected from the 1st week of December to 4thweek of March. Aphid incidence sharply increased and reached its peakon 2nd week of January (10.6 adults/3 leaves) on BD-10154 followed by BD-10158, BARI Begun-1 and BD-7320.At that week, aphid showed lower number of incidence on BARI Begun-5, BARI Begun-6, BARI Begun-8 and BARI Begun-9.

With the advent of time and plant growth, the population again started increasing and reached its peak on 2nd week of February (9.5 adults /3 leaves) on BARI Begun-9 followed by BARI Begun-5, BARI Begun-8, BD-10158 and BD-10154. At that week aphid showed lower incidence on BD-7320 followed by BD-9952, BARI Begun-4 and BARI Begun-6. Aphid population then declined on all the germplasms. Jafir *et al*. (2018) observed fluctuations of the abundance of aphid on different germplasms of brinjal in Faisalabad, Pakistan and reported the highest and the lowest abundance during 1st and 4th week of April, respectively.

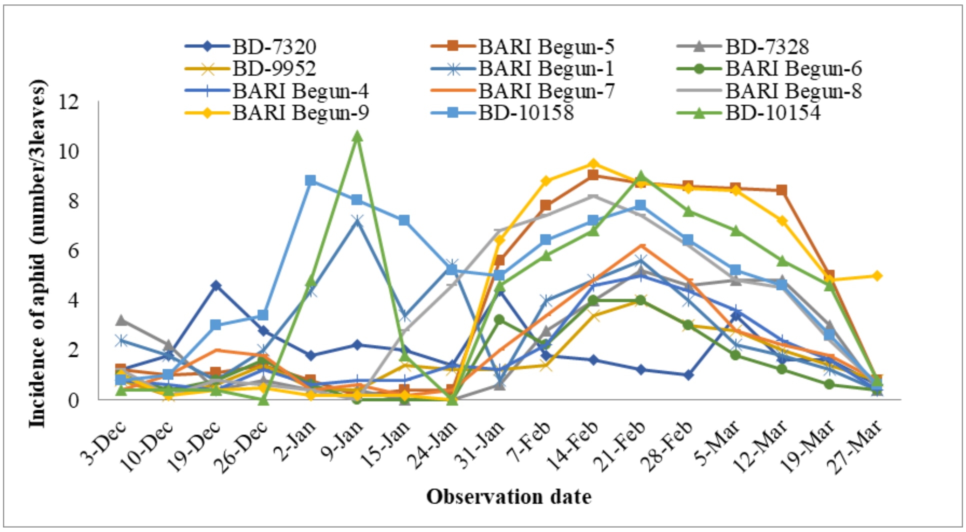

Fig. 1. Fluctuation of the incidence of aphid on brinjal germplasms during December 2018 to March 2019.

Infestation level of leaves of the tested germplasms was recorded from 1st week of December to 4thweek of March and found fluctuations (Figure 2). Percent leaf infestation reached a peak during 1stweek of December (19.8%) on BD-10158 followed by BD-10154, Begun-8, BARI Begun-9, BD-7320. Infestation level declined after 2nd week of December and showed similar result from 3rd week of December to 1st week of February on all the germplasms except BARI Begun-5 and BARI Begun-9. From 2nd week of February, aphid showed higher level of infestation on all the tested germplasms. The highest infestation was recorded during 2nd week of March (21.5%) on BARI Begun-5 followed by BD-10154, BD-10158, BARI Begun-1, BARI Begun-7 and BD-7320.At that week, the lowest infestation was found on BD-9952.The present findings showed that infestation of aphid on different germplasms had variations and fluctuated throughout the study which is supported by Mundi *et al*. (2011) who reported 10.0%-15.0% infestation of brinjal by sucking insects like aphid and jassid.

The meteorological parameters indicated that during 1st week of December when aphid population was first recorded, the maximum and minimum temperatures were 27.0ºC and 14.0 ºC, respectively. At that time relative humidity was 91%, and there was no rainfall (Table 1). At 1st week of January when aphid population started rising, the maximum and minimum temperatures were 27.5ºC and 11.0ºC, respectively, the relative humidity slightly declined 89%, and there was no rainfall. The highest aphid population was recorded in the 2nd week of February and at that time maximum and minimum temperatures, relative humidity were 28.5ºC, 14.5ºC and 81% respectively, and there was no rainfall.

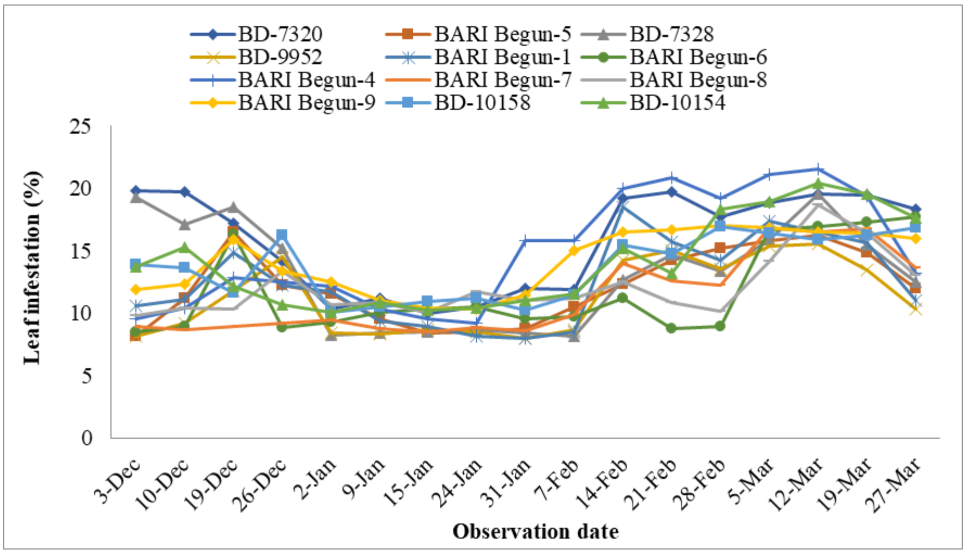

Fig. 2. Infestation level of aphid on brinjal germplasms during December 2018 to March 2019.

Table 1. Data regarding weekly observations on different meteorological parameters

Observation date	Temperature °C		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
03.12.18	27.0	14.0	91	0.0
10.12.18	26.0	12.5	90	0.0
19.12.18	17.0	16.0	90	2.6
26.12.18	26.0	11.0	79	0.0
02.01.19	27.5	11.0	89	0.0
09.01.19	26.0	11.0	90	0.0
15.01.19	26.0	12.0	80	0.0
24.01.19	28.5	12.0	90	0.0
31.01.19	24.0	10.0	90	0.0
07.02.19	27.0	11.5	90	0.0
14.02.19	28.5	14.5	81	0.0
21.02.19	30.0	16.0	83	0.0
28.02.19	27.0	19.0	90	23.38
05.03.19	25.5	19.0	90	10.39
12.03.19	31.0	22.0	92	0.0
19.03.19	30.0	19.0	76	0.0
27.03.19	34.0	21.0	75	0.81

Correlation between incidence of aphid and meteorological parameters is shown in Table 2. Abundance of aphid showed significant positive correlation with maximum temperature for all the tested germplasms except BD-7328, BD-10158 and BD-10154. Incidence of aphid showed significant positive correlation with minimum temperature for all the tested germplasms except BARI Begun-1, BD-10158 and BD 10154. The findings were similar to Rao *et al.*(2013)who reported that aphid population was regulated by warm temperature. Incidence of aphid on all the germplasms showed non-significant negative correlation with relative humidity. Rainfall had insignificant negative correlation with the incidence of aphid on BD-7320, BARI Begun-1, BARI Begun-4, BARI Begun-7, BARI Begun-8, BD-10158 and BD-10154. The present study showed that rainfall occurred in the 3rd week of December, 4th week February, 1st week of March and at the end of the study when aphid population declined on all the germplasms. The result is in accordance with the findings of Patel *et al.* (2015) who reported that rainfall had negative impact on aphid population.

Table 2. Correlation between the abundance of aphid on brinjal germplasms and meteorological parameters

Germplasm	Weather factors			
	Max Temp.(^{0}C)	Min Temp.(^{0}C)	RH (%)	Rainfall (mm)
BD-7320	0.687**	0.481*	-0.452^{NS}	-0.289^{NS}
BARI Begun-5	0.498*	0.814**	-0.279^{NS}	0.361^{NS}
BD-7328	0.369^{NS}	0.887**	-0.083^{NS}	0.377^{NS}
BD-9952	0.566*	0.823**	-0.303^{NS}	0.207^{NS}
BARI Begun-1	0.540*	0.092^{NS}	-0.094^{NS}	-0.277^{NS}
BARI Begun-6	0.509*	0.766**	-0.281^{NS}	0.120^{NS}
BARI Begun-4	0.703*	0.696**	-0.419^{NS}	-0.205^{NS}
BARI Begun-7	0.483*	0.688**	-0.347^{NS}	-0.157^{NS}
BARI Begun-8	0.561*	0.532*	-0.350^{NS}	-0.211^{NS}
BARI Begun-9	0.544*	0.575**	-0.263^{NS}	0.052^{NS}
BD-10158	0.344^{NS}	0.019^{NS}	-0.199^{NS}	-0.079^{NS}
BD-10154	0.452^{NS}	0.216^{NS}	-0.151^{NS}	-0.241^{NS}

NS = Non significant, * = Significant, ** = Highly significant

Correlation between abundance of aphid and predator is shown in Table 3. Abundance of aphid showed highly significant positive correlation with both lady bird beetle and spider population for all the tested germplasms. The present finding showed agreement with Soni *et al.* (2008) who found density dependent relationship between aphid and ladybird beetle *Coccinella septumpunctata*. Kamal *et al*. (1992) reported that spiderhad good predatory potentiality to control most of the sucking pests like aphid, jassid and whitefly.

Table 3. Correlation between the abundance of aphid and predator on brinjal germplasms

Germplasm	Predator	
	Lady bird beetle	Spider
BD-7320	0.832**	0.854**
BARI Begun-5	0.943**	0.778**
BD-7328	0.731**	0.939**
BD-9952	0.935**	0.941**
BARI Begun-1	0.931**	0.688**
BARI Begun-6	0.873**	0.948**
BARI Begun-4	0.955**	0.983**
BARI Begun-7	0.980**	0.963**
BARI Begun-8	0.991**	0.961**
BARI Begun-9	0.960**	0.979**
BD-10158	0.983**	0.967**
BD-10154	0.969**	0.956**

** = Highly significant

The present study showed that aphid had different levels of abundance and infestation on the tested germplasms, and depicted fluctuations throughout the study. The differences of the abundance and infestation of the pest may be due to the variations of the growth stages of the germplasms to weather conditions, and number of abundant predators. Other factors like variations of the number of leaf trichomes. leaf thickness and toughness, pH, cell sap, content of moisture, sugar, protein, minerals or tanin in the leaf of the germplasms may affect the abundance and infestation of the pest. During the peak season, aphid incidence and infestation was lower on BARI Begun-6, BARI Begun-8,BARI Begun-9 and BD-9952. These germplasms could be cultivated in the areas where aphid is a major pest of brinjal. Further studies are needed for finding out resistance characteristics which could be useful for development of new variety.

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VALUE CHAIN ANALYSIS OF FREE FATTY ACID OF RICE BRAN OIL IN BANGLADESH

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AND M. S. RAHMAN[5]

Abstract

The study was conducted at Emerald oil mill and Poultry Industries Limited, Sherpur and Square Toiletries Ltd. at Shalghoria, Pabna to assess the financial analysis of the rice bran oil mill and to determine the value chains system of rice bran edible oil chemical by-products specially free fatty acid and actors involved in marketing of FFA in Bangladesh during the year 2013-2014. Tabular and statistical analyses were done. Results revealed that the rice bran edible oil was produced as the main product (7948 t/mill/year), and de-oil rice bran (39600 t/mill/year), free fatty acid (1495 t/mill/year), gum (332 t/mill/year), wax (329 t/mill/industry) and splint earth (808 t/mill/industry) products were also produced as chemical by-products in oil mill. Free fatty acids, gum and wax were used in soap factories. The oil mill purchased 49,500 tonnes of rice bran annually. Total cost of production was estimated at lakh Tk. 13969.85 and total variable cost was lakh Tk. 13032.98. Gross return of the oil mill was calculated at lakh Tk. 14838.03/year and lakh Tk. 867.10 was obtained from free fatty acids annually. The net profit lakh TK. 868.18/year/ industry was achieved from rice bran, while the FFA earned Tk. 30344 per ton as net profits. The benefit cost ratio was 1.06 in the oil mill. The higher return on investment was gained in free fatty acid. Minimum marketing cost was found in shorter chain-I (Oil mill – soap factory) and longer chain-III (Oil mill – Commission agent 1 – Commission agent 2 – Soap factory) produced maximum marketing cost in the FFA value chain system. Total marketing margin and total profit were achieved Tk. 10.50/kg and Tk. 2.90/kg, respectively. Free fatty acid as a chemical by-product in rice bran oil processing has esteemed market value in soap factories that contribute to the national economy.

Keywords: Rice bran edible oil, Free fatty acid, Profitability, Value chain

Introduction

Rice is the main cereal crop in Bangladesh and its production was about 35.85 million tonnes in 2019-20 (USDA, 2021). Rice kernels are composed of roughly 20% rice husk, 11% bran layers, and 69% starchy endosperm in milled rice

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(Dhankhar, 2014). Moreover, rice bran, rice husk, and broken rice are used as industrial and bioactive products for humans and animals (Rohman *et al*., 2014). The potential bran oil production is found to be 0.134 to 1.05 million tonnes of rice bran in Bangladesh and about 35 oil mills need to be established with a minimum capacity of 100 tonnes bran per day with 300 days per year. Such a rice bran oil mill can produce about 12.8 tonnes edible oil per day (Rahman, 2009). Twenty five lakh tonnes bran are produced in our country whilst RBO industries utilizes only 13 lakh tonnes of rice bran to produce 2.58 lakh tonnes of rice bran oil, rest of the bran is used in poultry farm or fish industries. But domestic sources can provide 36.15 lakh tonnes rice bran (Ali *et al.,* 2015).

Approximately, ∼10–23% rice bran oil (RBO) is found in rice bran (Friedman, 2013). Rice bran consists of fat (10-23%) and unsaponifiable components (4.2%) (Sharif *et al*., 2014). Rice bran oil contains raw oil 21.44% and its constituents of unsaturated fatty acids as linoleic acid (35.26%), oleic acids (48.48%), palmitic acid (14.54%) and free fatty acid (8.15%) which are more nutritional and beneficial (Gul *et al.*, 2015; Zúñiga-Diaz *et al*., 2017). Chemical compositions of saturated and unsaturated rice bran free fatty acid in rice bran oil have added valuable utilization in cooking and industry, and alternative to palm oil (Oluremi *et al*., 2013). Free fatty acid (FFA) is obtained in the extracted rice bran oil that is defined as non-edible oil, while it is also used for soap production and animal feed (Rajan and Krishna, 2009). Higher amounts of free fatty acids release hydrolytic enzymes and the large amount of soaps are produced by using free fatty acids (Singh and Singh, 2009).

Exactly, rice bran contains 10-23% crude oil and 70-80% DORB. After refining of 10-23% crude oil, 78% edible oil and 22% chemical by-products are also found. Wax (2-3%), gum (2-3.5%) and free fatty acid (10-14%) are released as chemical by-products in the rice bran edible oil extraction process. The chemical by-products especially free fatty acid (FFA) results in good usage to soap factories and cosmetic factories, and its potential effect for value addition. Rice bran contains a high amount of three types of fatty acids such as palmitic, oleic and linoleic. The extracted fatty acids in rice bran help in raising high-density lipoprotein (HDL) as "good cholesterol." Distilled rice bran fatty acid contains vitamin E complex lipids, lecithin, tocotrienol, T_3squalene, phytosterol 5% and 2.5% oryzanol. They are used in dressing and frying, and it is an excellent raw material for food making. Rice industrial by products management for oil extraction and its value added products (cookies & leavened pan bread) are studied (Sharif, 2009). The physical and chemical characteristics of rice bran, fatty acid profile and antioxidants potential of rice bran sample are also analysed (Sharif, 2009).

Evidently bran comes from rice mills that are utilized in the rice bran oil mill at a large scale. Rice bran edible oil is the main product of the rice bran oil mill. On the other hand, FFA is an important by-product and a huge amount of FFA is produced each year. The FFA is a very efficient ingredient for soap making purpose. The oil miller sells the FFA to the soap factory through commission agents. Finally FFA is used to make the Chaka laundry soap and Chaka ball soap under Square toiletries Ltd., and the end user of the FFA is Laundry soap and Ball soap consumer.

Many commission agents in the supply chain system earn a huge amount of money between distributor and local market (BIFT, 2016). Consequently, value is changed in transportations. Product quality in each step of the supply chain is predicted early while good flows can be controlled and comprehensive chain results in quality product availability and less product losses in retailers (Van Der Vorst *et al*., 2014).

Eventually, the value chain is an important element in improving profitable business. As the service progresses in the value chain, it adds value with the company to turn a profit by the time and the product or service is finally delivered to the consumer. Value chain is the whole series of activities that create and build value at every step. However, in-depth analysis of the value chain of rice bran oil chemical by-products FFA has contributed to efficient utilization for better economic return. Moreover, no research finding in published form on value chain analysis of rice bran free fatty acid was found before this study in Bangladesh. But it is important for business men and policy makers for better utilization of FFA. With this view in mind, the present study was designed with the following specific objectives:

1. To assess the financial analysis of the rice bran oil mill;
2. To determine the value chains system of rice bran edible oil chemical by-products specially free fatty acid and actors involved in marketing of FFA in Bangladesh and
3. To identify the key constraints to FFA usages and its opportunities in soap factory.

Materials and Methods

The study was conducted at two factories such as Emerald oil mill and Poultry Industries Limited, Sherpur and Square Toiletries Ltd. at Shalghoria, Pabna. Square Toiletries Ltd. Shalgaria, Pabna factory produced Chaka ball soap and Chaka laundry soap. The Rice Bran Free Fatty Acid (FFA) was used in making soaps.

Survey questionnaire: A set of semi-structured questionnaire was prepared to collect data from key informants (KI) experts from the relevant fields and selected rice bran oil mill as well as soap factory. Besides, a checklist was developed for KIs. The draft questionnaires and checklist were pre-tested and necessary corrections, modification and alterations were prepared accordingly.

Finally data were collected from KIs using pre-tested questionnaire during the year 2013 - 2014.

Analytical techniques: The collected data were analyzed by tabular and statistical methods. The profitability of the rice bran oil mill and soap factory was examined on the basis of gross margin, net return and rate of return over cost.

Cost estimation: Profitability of FFA in the processing of rice bran oil and soap production was calculated on the basis of financial analysis as fixed and variable costs. Fixed costs were the costs that were independent from the size of production. Fixed costs generally included as depreciation (D), interest on investment (I), taxes (T), insurance (In) and cost of housing or shelter (S). These were dependent on the calendar year and they were used independently. Depreciation cost of the machine was determined by the Sinking Fund Method.

Interest on investment was determined using the following formula:

Interest on investment, $I = \left(\frac{P+S}{2}\right) \times I$

Where, P= Purchase price, S = Salvage, i = Interest rate

Interest on investment was taken as average value considering 10% interest rate. The cost of taxes was considered as 1.4% purchase price of the machine and equipment. The cost of insurance was considered at 0.25% of purchase price of the machine and equipment. The rice miller has to pay the amount of money for the land or the value, he gets from the investment of the rice mill area was considered as opportunity cost of land. The depreciation cost of the building was determined by the Sinking Fund Method also assuming the life of the brick building 100 years and the metal roof sheds 50 years.

In a small mill, staff salary is negligible because mill owners themselves operate and maintain the mill. Sometimes they use labour for operation. Current value of the salary for the staff was considered as management cost.

Variable costs of rice bran processing oil mill were estimated by the cost of bran, labour, chemicals, repair & maintenance, electricity used of the machines etc. as per year basis.

Returns: Returns were calculated by multiplying the volume sold (Q) with the selling price (P) and, subsequently, by adding additional sources of income, such as revenues of selling the production waste of a product.

Returns = $(Q \times P)$

Where Q = Volume of product sold, kg

P = Selling price Tk/kg

Value chain analysis:

Analytical technique of value chain: The collected data and information were summarized to tabular form which included classification of tables in meaningful results by using the arithmetic mean, percentage and ratio. For FFA marketing, the involvement of intermediaries in marketing channels were identified, and marketing costs and margins were determined by using the following formula and the estimated values were placed in tables for understanding. Supply chain, value chain and value addition to FFA was shown by flow channel.

Marketing cost: Marketing cost was the sum of transport cost, storage cost, labour cost and other costs that were associated with moving commodity from the point of purchase to the customer or final consumer. The total marketing cost was determined by the following formula

$$Tc = Cp + \sum Mci$$

Where, i=1; Tc= Total cost of marketing; Cp= Producer cost of marketing; Mci= Marketing cost by the ith trader

Marketing margin: The absolute margin of the middleman, wholesaler, trader and retailers was determined as follows

$$Mm = Psa - (Pba + Mc)$$

Where, Mm = Marketing margin; Psa = Selling price; Pba = Buying price; Mc = Marketing cost. The cost of marketing was calculated and the lowest cost of marketing channel was ranked I and that of the highest cost marketing channel was considered as last one. The same approach was followed in ranking the margin of middlemen in each channel.

Results and Discussions

Emerald oil mill and Poultry industries Ltd: Basic information was recorded on various items of Emerald oil mill and Poultry Industries Ltd. factory which was founded in 2008 covering 1.22 ha land (Table 1). The total number of manpower (permanent and temporary) was 350 and its establishment cost was at lakh Tk.5000. Rice bran oil (7948 tonnes) was produced as the main product and byproducts were released as 39600 tonnes DORB, Free fatty acid 1495 tonnes, Wax 329 tonnes, Gum 332 tonnes and 808 tonnes of splint earth in a year. Various chemicals viz. 74250 tonnes, 4455 tonnes, 22275 tonnes, 495000 tonnes, 83655 tonnes, 51975 tonnes and 495 tonnes were used in hexane, citric acid, phosphoric acid, bleaching earth, activated carbon, salt and costic soda, respectively in rice bran oil processing. Laboratory chemicals were also required at lakh Tk. 20.00 in this factory. These chemicals were needed in different steps of processing rice bran oil. Hexane was applied for separation of DORB from crude rice bran oil. Citric acid and phosphoric acid were required for the degumming process in the oil refining sector. Bleaching earth was used to reduce the color of bran oil and also separated the splint earth. Application of Nacl in the boiler section and costic soda were used for the separation of FFA from the rice bran edible oil.

Square Toiletries Ltd: The factory was established in 1988 and its area was 0.18 ha. The factory had permanent manpower of 150 numbers and temporary manpower was 50 numbers. The factory produced 5000 tonnes of Chaka laundry soaps and Chaka ball soaps, and its turnover was attained at lakh Tk. 48300, while its establishment cost required lakh Tk 60000. Different chemicals such as 750 tonnes, 1750 tonnes, 150 tonnes, 600 tonnes, 500 tonnes and 0.65 tonnes were required in NaOH, palm fatty acid, coconut oil, RBD (Refined, bleached, and deodorized) palm stearin, palm oil and nerolin yeara yeara, respectively in soap production during the year 2013.

Table. 1. Basic information of Emerald oil mill and Poultry industries limited, and Square Toiletries Ltd. Shalghoria, Pabna

Items	Emerald oil mill and Poultry Industries Ltd.	Items	Square Toiletries Ltd. Shalghoria, Pabna
Factory area (ha)	1.22 ha	Factory area (ha)	0.178 ha
Establishment year	2008	Establishment year	1988
Total manpower (nos.)	350	Total manpower (nos.)	permanent 150 Temporary 50
Establishment cost (lakh Tk.)	5000	Establishment cost (lakh Tk.)	60000
Main product (t/yr):		**Main product (t/yr):**	
Rice bran oil	7948	Chaka ball soaps and Chaka laundry soaps	5000
By-products (t/yr):		Turn over ((lakh Tk.)/yr	48300
De-Oil Rice Bran (DORB)	39600	Naoh (t/yr)	750
Free Fatty Acid (FFA)	1495	Palm fatty acid (t/yr)	1750
Wax	329	Coconut oil (t/yr)	150
Gum	332	RBD palm stearin (t/yr)	600
Splint earth	808	Palm oil	500
Used raw materials (t/yr):		Nerolin yeara yeara (t/yr)	0.65
Rice bran	49500		
Hexane (T/yr)	74250		
Citric acid (T/yr)	4455		
Phosphoric Acid (T/yr)	22275		
Bleaching Earth (T/yr)	495000		
Activated carbon (T/yr)	83655		
Nacl (T/yr)	51975		
Costic Soda (T/yr)	495		
Laboratory chemicals (Tk/yr)	20.00		

Annual cost of production of rice bran oil and its by-products FFA

The annual cost of production was calculated on the basis of total variable cost and total cost. The annual total cost of production of rice bran oil was estimated at lakh Tk. 13969.85 and its by-products FFA achieved at lakh Tk.13032.98 per industry (Table 2). Rice bran cost was composed of the lion share (76.77%) of total cost followed by fixed cost (6.71%), while interest on operating capital attained 4.44% and chemical cost was 4.33%. Similar findings were reported by Kabir *et al.* (2016).

Table 2. Annual cost of production of rice bran oil and its by-products FFA

Item	Cost (lakh Tk./industry/year)	% of total cost
A. Fixed cost		
Depreciation of machines	11.06	0.08
Interest on investment on machines	163.35	1.17
Taxes	25.20	0.18
Insurances	4.50	0.03
Stuff salary	550.00	3.94
Depreciation of building	0.26	0.00
Interest on investment on building	181.50	1.30
Opportunity cost of land	1.00	0.01
Total fixed cost (A)	**936.88**	**6.71**
B. Total Variable cost		
Rice bran	10724.18	76.77
Labour	88.78	0.64
Repair and maintenance	200.00	1.43
Electricity	0.72	0.01
Gas bill	432.00	3.09
Lubricant	350.00	2.51
Tax	12.00	0.09
Chemical cost :	604.69	4.33
Interest on operating capital	620.62	4.44
Total variable cost (B)	**13032.98**	**93.29**
Total cost (A+B)	**13969.85**	**100.00**

Annual outputs and returns from rice bran oil and its by-products FFA

Annual outputs: Annual total quantity of outputs of rice bran oil and its by-products FFA etc. was found to observe 50512 t/industry as presented in table 3. The main product rice bran oil (packed oil and loose oil) was computed at 7948 t/industry/year that is 16% of total rice bran, while the DORB, FFA, Wax, Gum and Splint earth were 39600, 1495, 329, 332 and 808 t/industry/year, respectively. Similar result was found by (Friedman, 2013). Ali *et al.*, (2015) reported that 7.96 lakh tonnes bran oil was produced from 38.5 lakh tonnes of rice bran. Ali *et al.* (2015) also observed that DORB was found as a by-product in pellet form in crude oil processing and it was used for feed production. Henderson *et al.* (2012) reported that rice bran oil, which has some components with biological effects is attributed with fatty acid and flavonoid. The Highest amount of edible oil 7948 t/year and valuable by-products as DORB, free fatty acid, gum, wax and splint earth were exerted in bran oil processing as reported (Kabir *et al.*, 2016).

Annual returns: Annual total returns of rice bran oil and its by-products FFA etc. was earned lakh Tk. 14838.03/industry (Table 3). Maximum (53.19%) share of returns was observed in rice bran oil and minimum share (0.11%) was in both gum and splint earth, while FFA exhibited (5.84%). It was evident that 15.74% refined oil was found to occur in crude oil and the free fatty acid showed 2.96%. Kabir *et al.* (2016) found that maximum return was obtained from refined oil in bran oil processing and remarkable return was obtained in FFA while gum and splint as minimum.

Table 3. Annual outputs and returns from rice bran oil and its by-products FFA

Items	Quantity (t/industry/year)	Price (Tk/lt/kg)	Return (lakh Tk/industry/year)	% of total returns
Packed oil	155 (0.31%)	165	255.75	1.72
Loose oil	7793 (15.43%)	98	7637.14	51.47
DORB	39600 (78.39%)	15	5940.00	40.03
Free Fatty Acid	1495 (2.96)	58	867.10	5.84
Wax	329 (0.65%)	32	105.28	0.71
Gum	332 (0.66)	5	16.60	0.11
Splint earth	808 (1.60)	2	16.16	0.11
Total	**50512**		**14838.03**	100.00

Profitability of rice bran oil and its by-product FFA production

The annual gross margin and net return/profit of rice bran oil and its by-product FFA etc. was estimated at lakh Tk. 1805.05/industry and lakh Tk. 868.18/industry, respectively (Table 4). The benefit cost ratio of rice bran oil and its by-product FFA etc. was obtained 1.06. The annual net margin of the rice bran oil and its by-product FFA etc. showed at lakh Tk. 1718.76/industry while return on investment marked 0.06/industry. The net profit of rice bran oil mill was lakh Tk. 636.07 as studied by Kabir *et al.* (2016).

Rice bran oil: The total cost of rice bran edible oil per ton was calculated at Tk. 27656 and total variable cost was Tk. 25802 (Table 4). Gross return, gross margin and net return of rice bran edible oil per ton was found to have Tk. 99307, Tk. 73505 and Tk. 71650, respectively. Total costs and variable costs were determined by Kabir *et al.* (2015) in a survey report of the rice bran oil mill. Both gross return and net return resulted in significant output of rice bran edible oil in bran oil processing in Emerald oil mill that investigated the ways for further study as the factory was profitable.

Table 4. Profitability of rice bran edible oil and FFA production

Items	Industry/year
Gross return (lakh Tk)	14838.03
Total cost (lakh Tk)	13969.85
Total variable cost (lakh Tk)	13032.98
Gross margin (lakh Tk)	1805.05
Net return/profit (lakh Tk)	868.18
Benefit cost ratio	1.06
Net Margin (currency)	1718.76
Return on investment	0.06
Cost of rice bran edible oil (Tk/ton) @TC	27656
Cost of rice bran edible oil (Tk/ton) @TVC	25802
Return of rice bran edible oil (Tk/ton)	99307
Net return of rice bran edible oil (Tk/ton)	71650
Gross margin of rice bran edible oil (Tk/ton)	73505
Cost of FFA (Tk/ton) @TC	27656
Cost of FFA (Tk/ton) @TVC	25802
Return of FFA (Tk/ton)	58000
Net return of FFA (Tk/ton)	30344
Gross margin of FFA (Tk/ton)	32198

Free Fatty Acid (FFA): The cost of FFA per ton was calculated at Tk. 27656 and Tk. 25802 on the basis of total cost and total variable cost, respectively (Table 4). Gross return, gross margin and net return of FFA per ton was found to be Tk. 58000, Tk. 32198 and Tk. 30344, respectively. Total cost and net return of

FFA in this study were found to show profound effect in rice bran oil processing as its importance in value chain analysis.

Mapping the Value Chains

The value chain mapping of FFA in graphical form and all the major actors of oil and FFA processing value chains were presented. It involved the main actors in the processes, flows of products with volume percentage in the value chain.

Actor mapping in FFA value chain

Actor mapping is one of the important steps in value chain analysis. Actor mapping showed the performance of the people who were involved in the chain. Mapping of FFA was started from a rice mill. Commission agents collected the bran from the automatic and semi- automatic rice mills and delivered to the oil mills. Bran oil was extracted from rice bran with the chemicals in the oil mill extraction process, and refined oil was gained from crude oil. As a result, FFA, DORB, wax, gum and splint earth were produced as the main oil milled by-products. There were so many chains observed in the value chain system of FFA. One was: the oil miller sold the FFA to the soap factory directly. Another was: the oil miller sold the FFA to the commission agents and they sold to soap factory and the third was: the oil miller sold the FFA to the commission agents and they sold to another commission agents and the second commission agents sold to the soap factory. The actor mapping of the FFA value chain is shown in Figure 1.

Actor mapping of FFA value chain

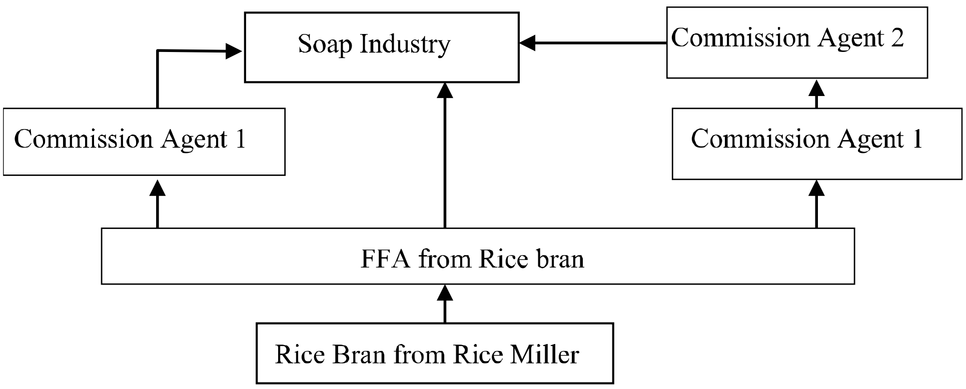

Fig. 1. Flow diagram of Actor mapping of FFA value chain.

Product mapping with volume percentage in FFA value chain

In the oil mill by processing rice bran, rice bran edible oil was found as the main product. Different types of chemicals and mechanical procedures were used for the extraction of rice bran edible oil and FFA etc. Crude oil was separated from the rice bran after the extraction process and the retained rice bran was called DORB. Free fatty acid was obtained from chemical by-products. The FFA was used in soap factories for making soap. The flow of products is shown in Figure 2.

Volume Mapping of FFA Value Chain

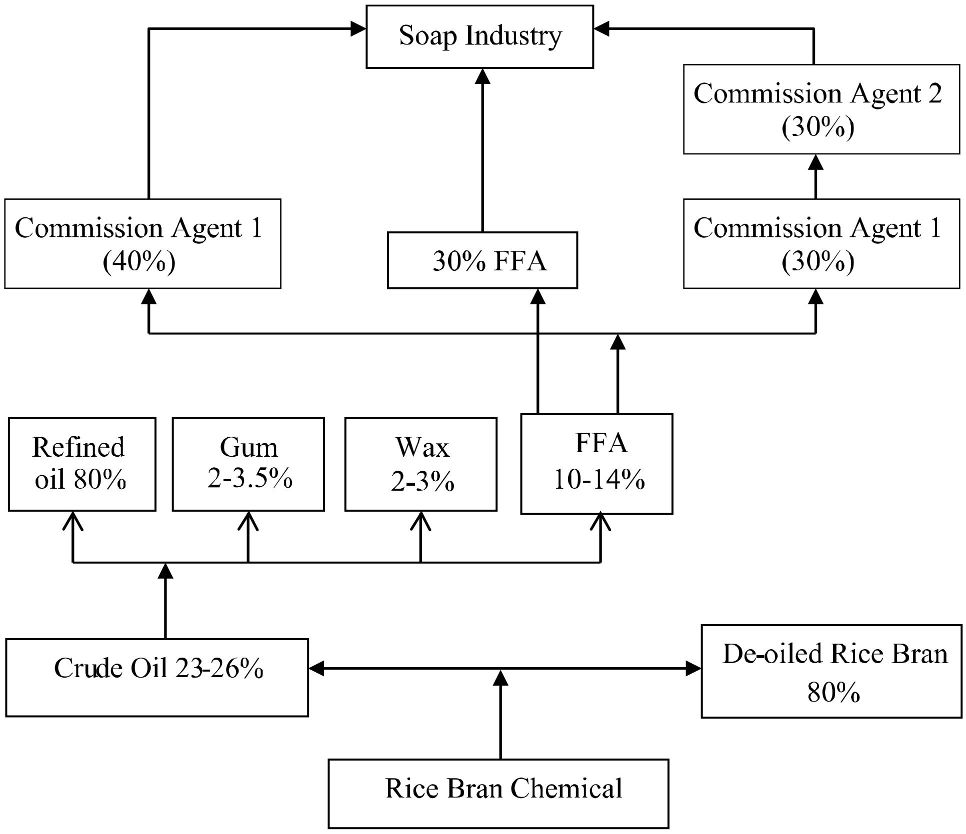

Fig. 2. Flow diagram of product mapping with volume of FFA value chain.

Marketing cost of FFA

Marketing costs narrated the cost of performing various marketing functions which were needed to transfer a commodity from the place of production to the ultimate consumers. Mainly FFA was marketed in three ways where commission agents were found to be involved. Marketing costs for each kg of FFA were estimated to be Tk. 0.45, 1.99 and 2.06 for oil mill owner, commission agents and soap factories, respectively (Table 5).

Supply chains of the FFA marketing

Chain-I: Oil mill ⟶ Soap factory

Chain-II: Oil mill ————→ Commission agent 1 ————→Soap factory

Chain-III: Oil mill ————→Commission agent 1————→Commission agents 2 ————→Soap factory

Table 5. Total marketing cost of stakeholders and intermediaries involved in FFA marketing (Tk/kg)

Cost items	Oil mill	Commission agents 1	Commission agents 2	Soap factory
Transportation, loading and unloading	0.15	1.22	1.22	1.22
Drum fare	0.00	0.41	0.41	0.41
wages	0.00	0.17	0.17	0.17
Godown fare	0.15	0.00	0.00	0.12
Security	0.05	0.00	0.00	0.05
Electricity	0.05	0.00	0.00	0.05
Telephone	0.05	0.05	0.05	0.05
Personal expenses	0.00	0.15	0.15	0.00
Total	0.45	1.99	1.99	2.06

Marketing margin and profitability of FFA marketed

Marketing margin was the price of all utilities with activities and functions that were performed by the intermediaries (Kohls and Uhl, 2005). Marketing margin was the percentage of the final weighted average selling price taken by each stage of the marketing chain. The margin covered the costs that were involved in transferring produce from one stage to the next and provided a reasonable return to those actors in the marketing activities (Crawford, 1997). Kaplinsky and Morris (2000) reported that the value chain explained that it was needed to transfer a product in different channels of production to the final consumer.

Marketing margin under Chain-I, Chain-II and Chain-III were calculated at Tk.2.51/kg, Tk. 3.74/kg and Tk. 4.24/kg, respectively (Table 6). Marketing profit was found to be Tk. 1.30/kg and Tk. 1.60/kg in Chain-I and Chain-II, respectively. In chain-I, there was no marketing profit because the soap factory purchased FFA directly from the oil mill. Total marketing margin and profit were Tk.10.50/kg and Tk. 2.90/kg, respectively. From the above findings, a significant amount of money was earned due to many commission agents in the supply chain system from distributor to local market which was studied by BIFT, 2016. Consequently, value was changed in transportations. Van Der Vorst *et al*. (2014) also reported that the supply chain was predicted in each step for product quality that showed quality product availability and fewer losses of product to the end user.

Table 6. Marketing margin and marketing profit of FFA (Tk./kg)

Particulars	Chain-I	Chain-II	Chain-III	Total marketing margin and profit
Purchase price (PP)	58.00	58.00	58.00	-
Marketing cost (MC)	2.51	2.44	2.64	-
Sales price (SP)	60.51	61.74	62.24	-
Marketing margin (MM=SP-PP)	2.51	3.74	4.24	10.50
Marketing profit (MP=MM-MC)	0.00	1.30	1.60	2.90

Constraints to rice bran FFA production and marketing in soap factory

The industries were hard hit by frequent load shedding of electricity that increased the cost of production. Capacity building of engineers, mechanics and skilled technicians were other major constraints to production. More commission agents may also increase the marketing cost of FFA production and marketing in the value chain system. Sometimes the soap factory was encountered in difficult situations to collect the quality free fatty acid from the rice bran oil mill. It is urged to think that chemical analysis of rice bran FFA with specified proportion of properties that are needed to be rendered as further study in alternate use of imported palm fatty acid for soap production.

Prospects of FFA in soap factory

Two types of soaps were produced such as Chaka ball soap and Chaka laundry soap in Square Toiletries Ltd. Imported palm FFA was used in making Chaka ball soap and Chaka laundry soap. Square Toiletries Ltd. imported palm FFA acid from Malaysia at a price of Tk. 80/Kg but our country rice bran FFA is available at a price of Tk. 58/Kg. If the soap factory uses rice bran FFA, the production cost would be lower than the use of palm fatty acid in soap production all over the country. People would be benefitted by lower priced soap and more value addition was created for FFA. Besides this, Alam soap factory Ltd. also used the rice bran free fatty acid as an alternative of RBD palm stearin in making no. 1pocha soap and laundry soap, while RBD palm stearin was imported at a price of Tk. 85/kg.

Free fatty acids were non-volatile monocarboxylic compounds that were important constituents as base for laundry and toilet soaps were investigated by the researchers Berneckė and Maruška (2013). Singh and Singh (2009) studied that rice bran of its abundant free fatty acid with hydrolytic enzymes were used in the soap factories. Rajan and Krishna (2009) indicated that released free fatty acids from the extracted oil of rice bran were used in soap production.

Conclusions and Recommendations

Oil mill produced a handsome quantity of rice bran edible oil, DORB and FFA. Oil mill produced a large quantity of 7948 tonnes of edible oil, DORB (39600 tonnes) and FFA (1495 tonnes) and its edible oil reached 15.74% over crude oil. Financial analysis revealed that production of rice bran oil and FFA was profitable according to gross margin and net return. In value chain analysis, it was found that shorter chain incurred lower cost and longer chain increased the highest marketing cost. Total marketing profit was also noted as Tk. 2.90/kg in this value chain. Value addition of FFA was evidently signified in soap production. Rice bran edible oil mills should be given prioritized attention in order to produce more rice bran oil that limits in importing edible oil, palm fatty acid as well as RBD palm stearin to save foreign currency. Public and private sector enterpreneurs are needed to establish modern technology based several rice bran processing units in the country to increase the amount of edible oil production as well as increase the amount of by products as FFA, which is used as an ingredient for making soap that can save the huge amount of foreign currency and create employment generation significantly. Successful business development strategies are also required with necessary plan engineer, spare parts, skilled manpower, and availability of gas and electricity supply for utilizing FFA in soap factories. Further study regarding chemical analysis of rice bran FFA are needed for searching alternate use of imported palm fatty acid and RBD palm stearin for soap production.

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EFFICACY OF *Moringa oleifera* EXTRACT, *Trichoderma asperellum*, A SYNTHETIC FUNGICIDE AND CATTLE DUNG AMENDMENT IN THE INTEGRATED MANAGEMENT OF RICE BLAST DISEASE

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Abstract

This study evaluated the effect of integrated disease management on the incidence and severity of blast disease, and growth performance of rice. *Moringa oleifera* extract, *Trichoderma asperellum,* cattle dung and a synthetic fungicide were evaluated in sixteen treatment combinations using a susceptible IRAT 109 rice cultivar. The pot experiment was laid out in a randomized complete block design with three replications at the rooftop screenhouse of the Department of Crop Protection and Environmental Biology, University of Ibadan between May and October, 2019. Treatment with combination of *M. oleifera* extract, cattle dung and blastforce had the lowest disease incidence and mean severity of 16.8 and 7.5%, respectively which was significantly ($p<0.05$) lower than the standard positive check. Inoculated plants that were treated with a combination of *T. asperellum, M. oleifera* and cattle dung produced the highest yield of 7.6 tons/ha relative to control. This study showed that the combined application of naturally occurring biopesticides and cattle dung was more effective than single treatment in the management of rice blast disease.

Keywords: Blast disease, Biopesticide, Fungicide, *Moringa oleifera*, IRAT 109, Rice, Yield.

Introduction

Rice (*Oryza sativa* L.), is one of the three most important cereal crops grown as a primary source of food for over 3.5 billion people of the world's population and Nigeria accounts for about 8 million tonnes, which is the largest rice producer in Africa (FAO, 2019). The crop is known to be attacked by many diseases which cause huge losses annually, probably because it is usually produced in humid regions where climatic conditions are favourable for fungal infection. Among fungal diseases of rice, blast caused by *Magnaporthe oryzae* Couch. has been reported in more than 85 countries with over 30% of the annual rice harvest lost to infection (Dagdas *et al*., 2012). When young rice seedlings are colonized by rice blast pathogen, the whole plants often die and if it spreads to other parts of the plants, it results in nearly total loss of the rice yield (Kapoor and Abhishek, 2014).

The disease can be managed by use of fungicides, planting of resistant cultivars, biotechnological methods and through integrated approach (Ribot *et al.,* 2008; Hasan *et al*., 2016). However, indiscriminate and repeated application of fungicides has led to pathogen resistance and bioaccumulation in the food chain

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which discourage the adoption of this method. Resistant cultivars have been reported to be very effective in preventing fungal diseases, but new races of fungi that break down the resistance of rice cultivars make them vulnerable to diseases and thus unreliable (Hubert *et al*., 2015). Other management practices such as use of biological control agents, organic manure adopted singly and crop rotation have been found to be of limited use because of wide host range of the pathogen in most rice growing areas.

Moringa oleifera is a fast-growing evergreen plant in the tropics, which has been reported to possess antimicrobial properties (Anwar *et al*.,2007; Giri*et al*., 2010; Dania and Thomas, 2019). *Trichoderma* species abound in the rhizosphere and have been widely used in the control of plant diseases (Ritika and Utpal, 2014; Khalid, 2017; Dania and Gbadamosi, 2019). The application of organic manure to the soil enhances plant vigour and increases resistance to diseases (Amos *et al*., 2015). Integrated disease management is a cost effective approach to disease management of plants by combining biological, cultural and chemical methods with a minimum adverse effect on the environment. This study, therefore, evaluated the effect of integrated disease management on the incidence and severity of blast disease, and also growth and yield of rice.

Materials and Methods

Experimental site and sources of experimental materials

The experiment was conducted in the Phytopathology laboratory and roof top screenhouse of the Department of Crop Protection and Environmental Biology (CPEB), University of Ibadan, Ibadan, Nigeria between May and October, 2019. An isolate of *Trichoderma asperellum* and a susceptible IRAT 109 rice cultivar were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan, a synthetic fungicide (Blastforce) was purchased from an Agrotech store, *M. oleifera* leaves were obtained from the university premises while wheat seeds were purchased from the open market. Cattle dung used in this experiment was obtained from the Teaching and Research Farm of the University of Ibadan.

Preparation of growth medium and isolation of *Magnaporthe oryzae*

Dehydrated Potato Dextrose Agar (PDA) powder was prepared by dissolving 39 g/Lof sterile distilled water in a conical flask sealed with cotton wool and wrapped with aluminum foil. The mixture was autoclaved at a temperature of 121^{o}C and a pressure of 1.05 kg/cm^2 for 15 minutes. The medium was allowed to cool to about 45°C and afterwards 1 ml of lactic acid was added to inhibit the growth of bacteria contaminants. Twelve milliliter of the medium was dispensed per Petri dish aseptically in a laminar flow hood and allowed to set for 25 minutes.

Leaf samples of rice plant showing blast symptoms were collected from the rice field at International Institute of Tropical Agriculture (IITA), Ibadan and brought to the laboratory for isolation of the pathogen. The leaves were cut into smaller sizes measuring 3mm × 2mm using a sterile scalpel. The leaves were surface-sterilized with 10% sodium hypochlorite for one minute, rinsed in three changes of sterile distilled water and blot-dried on sterile filter paper before plating on PDA. The inoculated plates were incubated at 28 ± 2ºC for 4 days (Dania *et al*., 2015).

Identification of *M. oryzae* involved microscopic examination of the fungus and examining the cultural and morphological characteristics of the fungus using standard mycological charts (Barnett and Hunter, 2000; Kariaga*et al*., 2016) and following confirmation at the mycological herbarium of IITA.

Pathogenicity test

Four seeds of a susceptible rice cultivar IRAT 109 were sown in experimental pots; these were separately filled with 10 kg of sterilized sandy loam soil and later thinned to two stands per pot at one week after germination. Conidia were harvested from a two-week old culture isolates after full sporulation on PDA. An aliquot of 0.5 ml of a polyethylene sorbitol ester (Tween 80) and 10 ml of sterile distilled water were added to each Petri dish, to facilitate the detachment of the pathogen conidia and mycelia from the culture medium. The inoculum suspension was filtered through Whatman No 1 filter paper. The seedlings were inoculated with an inoculum concentration of 1×10^6 at three weeks after sowing using a hand sprayer. Control treatment were sprayed with only sterile distilled water. Inoculated plants were kept at 27-28°C in a screenhouse under alternating 12 h light and darkness, till 14 days after inoculation. Re-isolation and re-inoculation were done to establish Kock's postulates.

Preparation of treatments

Wheat seeds were soaked in sterile distilled water for 24 hours followed by decanting and washing with three changes of sterile distilled water. The seeds were then bottled and autoclaved at 1.05 kg/cm^2 pressure and 121ºC for 30min to kill any associated seed-borne pathogen. The sterilised seeds were allowed to cool for 5 h and then inoculated with a 4-day old culture of *T. asperellum* and incubated at 27-28ºC for 10 days to allow for mycelial ramification on the wheat seeds. *Moringa* leaves were air-dried for two weeks and ground to powder and 200g of it was dispersed (20% w/v) in 1 litre of sterile distilled water (SDW). The extract was left for 12 hours before use (Dania and Thomas, 2019). The synthetic fungicide (Blastforce) was prepared by dissolving 0.3g in 1litre of sterile distilled water according to manufacturer's instruction, which served as positive check. Cattle dung was applied at 20 g per pot and mixed thoroughly with the soil, which was equivalent to 7.5 tonnes/ ha^{-1} (Sudarsono*et al*., 2014).

Quantification of fungal spores and inoculation of rice plants

Spore suspension of *M. oryzae* was prepared by dispensing 10 ml of sterile distilled water to the Petri dish containing a 10-day-old culture of the fungus to dislodge the conidia and was filtered through a layer of cheese-cloth. Spores were counted by dispensing 0.1 ml of inoculum on a hemacytometer. Spore concentration was adjusted to 10^6 spore/ml according to Dania *et al*. (2015) and healthy rice plants with fully developed first four leaves were inoculated at 21 days. Plants inoculated with *M. oryzae* without any amendment served as control, while inoculated plants treated with Blastforce fungicide only served as positive check. Inoculated plants were covered with transparent polythene sheets overnight for 12 hours to create relative humidity needed to initiate infection. Five grammes of *T. asperellum* that has fully ramified on the carrier substrate were weighed and mixed with the top soil at one week after inoculation. Cattle dung was applied on the soil as previously described. *M. oleifera* leaf extract and Blastforce were applied as foliar spray at one week after inoculation. Data on growth parameters such as number of leaves, number of tillers, plant height, number of panicles, disease incidence and severity, were collected weekly, while yield parameters such as grain yield, grain weight, shoot dry weight, root dry weight and 100 seed weight were collected at the end of the experiment.

Determination of disease incidence and severity

Disease incidence was determined by counting the number of infected plants and expressed as percentage of the total number of plants assessed in each treatment:

$$\text{Disease incidence} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

Disease severity was assessed using the modified method of IRRI (2002):

1= No lesion observed;

2= Small brown specks of pinpoint size without sporulating spots;

3= Roundish to slightly elongated necrotic sporulating spots;

4= Narrow or slightly elliptical lesion;

5= Rapidly coalescing small, whitish lesion without distinct margins;

6= Severe blighting of leaves of infected plants;

Mean severity was determined according to the modified method of Asad*et al*. (2010):

$$\text{Mean severity} = \frac{\text{Sum of numerical ratings on a tree} \times 100}{\text{Total No. of disease symptoms on tree} \times \text{y}}$$

Where y = Number of severity rating

Evaluation of treatments for the management of blast disease of rice

The experiment was laid out in a randomized complete block design with sixteen treatment combinations and three replications. Each pot was filled with 10 kg of sterilized soil. Five seeds were sown directly in each pot and later thinned to 2 seedlings per pot after one week of germination. *Trichoderma asperellum*, *M. oleifera*, cattle dung and blastforce each alone or their combinations were considered as treatments as follows:

T_0= Rice plant inoculated without spray (control)

T_1 = Inoculated + *T. asperellum*

T_2 = Inoculated + *Moringa oleifera*

T_3 = Inoculated + cattle dung

T_4 = Inoculated + Blastforce

T_5 = Inoculated + *T. asperellum* + *M. oleifera*; T_1+T_2

T_6= Inoculated + *T. asperellum* + cattle dung; T_1+T_3

T_7 = Inoculated + *T. asperellum*+ Blastforce; T_1+T_4

T_8 = Inoculated + *M. oleifera* + cattle dung; T_2+T_3

T_9 = Inoculated + *M. oleifera* + Blastforce; T_2+T_4

T_{10}= Inoculated + Cattle dung + Blastforce; T_3+T_4

T_{11} = Inoculated + *T. asperellum* + *M. oleifera* + cattle dung; T_1+T_2+T_3

T_{12} = Inoculated + *M. oleifera* + cattle dung + Blastforce; T_2+T_3+T_4

T_{13} = Inoculated + *T. asperellum*+ Blastforce + *M. oleifera*; T_1+T_4+T_2

T_{14} = Inoculated + *T. asperellum* + cattle dung + Blastforce; T_1+T_3+T_4

T_{15} = Inoculated + *T. asperellum* + *M. oleifera* + cattle dung +Blastforce; T_1+T_2+T_3+T_4

Data analysis

Percentage data were transformed into arcsine angles to produce the approximate constant variance. All numerical data were analyzed using the Statistical Analysis System (SAS) Version 9.4 and means were separated according to Duncan Multiple Range Test (DMRT) at 5% level of significance.

Results and Discussion

Isolation and Pathogenicity test

Three fungal genera, *Aspergillus*, *Rhizopus* and *Magnaporthe* were isolated from the infected leaf samples in the laboratory. *Aspergillus* spp. and *Rhizopus* spp. were saprophytes or secondary invaders with very low frequencies of isolation. *Magnaporthe oryzae* was predominant and present in all infected leaf samples. The pathogen was characterised by the brown mycelia with grayish brown concentric rings when grown on Potato Dextrose Agar (PDA) culture (Figure 1a). The microscopic view showed a blue hyaline, spindle-shaped with tapering ends conidia with four septa singly and jointly fitted together (Figure 1b).

At two weeks after inoculation with *M. oryzae*, the leaves showed small brown spots at initial stage of infection which rapidly coalesced and developed into extensive spindle-shaped lesions with white central part and brownish borders typical of the disease (Figure 2). These results confirm previous reports of various authors that implicated *M. oryzae* as the causal organism of rice blast disease (Hajano *et al*., 2011; Rajput *et al*., 2017).

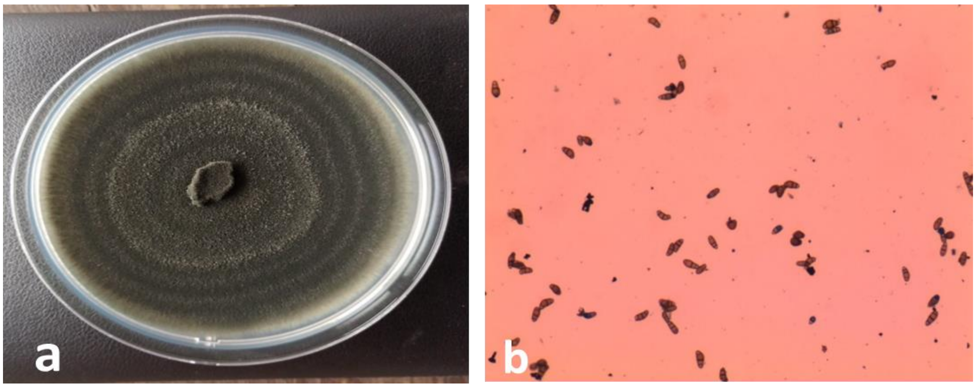

Fig. 1. Cultural (a) and morphological (b) characteristics of *Magnaporthe oryza.*

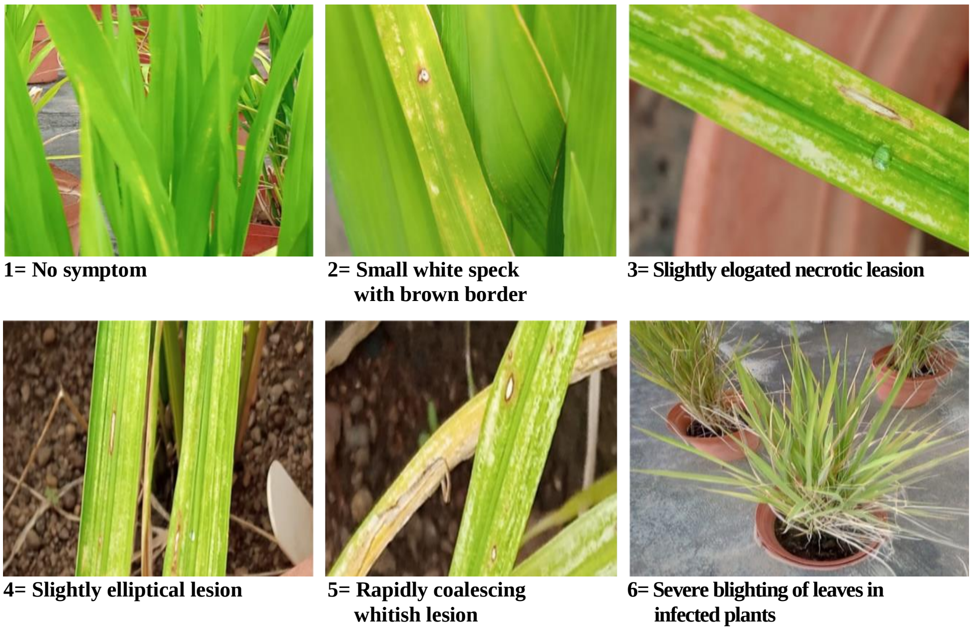

Fig. 2. Disease severity rating among rice plants inoculated with *Magnaportheoryzae.*

Table 1. Effect of *Moringa oleifera* extract, *Trichoderma asperellum*, blastforce fungicide and cattle dung amendment on the incidence and severity of rice blast disease

Treatment	Disease incidence (%)			
	Vegetative	Reproductive	Maturity	MS (%)
Inoculated and untreated rice plants (Control) (T_0)	30.0(33.20)a	32.5(34.72)a	45.8(49.08)a	51.2(53.31)a
T. asperellum (T_1)	16.7(24.12)b	22.2(28.71)b	26.50(30.97)ab	11.2(18.49)b
Moringa oleifera (T_2)	22.2(28.71)ab	27.0(31.13)ab	27.2(31.24)ab	14.2(21.70)b
Cattle dung (T_3)	27.2(31.24)a	27.2(31.24)ab	30.0(33.20)ab	16.7(24.05)ab
Blastforce (T_4)	22.2(28.71)ab	22.4(28.93)b	27.5(31.55)ab	14.2(21.70)b
T. asperellum + *Moringa oleifera* (T_5)	16.7(24.12)b	27.5(31.55)ab	27.5(31.55)ab	14.2(21.70)b
T. asperellum + cattle dung (T_6)	12.5(17.89)bc	22.2(28.71)b	22.2(28.71)b	10.2(18.49)b
T. asperellum + Blast force (T_7)	20.1(26.71)b	23.1(28.76)b	28.8(33.02)ab	14.5(21.68)b
M. oleifera + cattle dung (T_8)	16.7(24.12)b	22.2(28.71)b	22.2(28.71)b	10.2(18.49)b
M.oleifera + Blastforce (T_9)	24.7(29.87)ab	27.5(31.55)ab	27.5(31.55)ab	14.2(21.70)b
Cattle dung + Blastforce (T_{10})	12.5(17.89)bc	22.2(28.71)b	32.5(34.72)ab	20.1(26.71)ab
T. asperellum + *M. oleifera* + cattle dung (T_{11})	27.2(31.24)a	27.2(31.24)ab	32.5(34.72)ab	20.1(26.71)ab
M. oleifera + cattle dung+ Blastforce (T_{12})	12.5(17.89)bc	13.2(21.39)bc	16.8(24.14)c	7.5((13.83)bc
T. asperellum + Blastforce + *M. oleifera* (T_{13})	22.2(28.71)ab	22.8(28.93)b	23.1(28.71)bc	10.8(19.149)b
T. asperellum + cattle dung + Blastforce (T_{14})	22.3(28.80)ab	25.3(30.78)ab	27.5(31.55)ab	14.2(21.70)b
T. asperellum + *M. oleifera* +cattle dung + Blastforce (T_{15})	16.7(24.12)b	16.7(24.12)bc	22.2(28.71)b	10.2(18.49) b
S.E (±)	0.53	0.42	0.27	0.61
CV(%)	3.84	4.77	2.38	5.42

MS = Mean Severity. Means with the same letter along a column are not significantly different according to DMRT at $P \leq 0.05$. Percentage data were transformed into arcsine angles (in parenthesis) before analysis of variance (ANOVA).

Effect of treatments on incidence and severity of rice blast disease

Treatment T_{12} a combination of *M. oleifera* extract, cattle dung and Blastforce had the lowest disease incidence and mean severity of 16.8 and 7.5%, respectively which was significantly lower than T_4 with single application of the standard Blastforce fungicide that served as positive check (Table 1). Control plants (without treatment application) recorded the highest disease incidence and mean severity of 45.8 and 51.2%, respectively at maturity stage. Mean severity among the treatments ranged from 7.5 to 20.1%, which was significantly lower than the control (51.2%). Significant disease suppression was obtained in the plots treated with T_{12} (combination of cattle dung, *M. oleifera* extract and Blastforce).

The efficacy of *Moringa oleifera* agrees with previous report of Mazid*et al*. (2011) that the botanical produces phenolic compounds that are actively involved in disease resistance following the entry of pathogens into host plants. The toxicity of tannins and proanthocyanidins had direct effect on pathogens and these metabolites might also enhance resistance by contributing to healing of wounds through lignification of cell. (Lattanzio*et al*.,2006). The application of botanicals and bioagents has been identified as a sustainable tool in the management of plant diseases (Adandonon s*et al*., 2006). Rice blast is a systemic disease and *Trichoderma* species possessed the inherent ability to migrate through the stem and in the process reduced the incidence and severity of maize stalk rot disease (Sobowale*et al*., 2007). The significant reduction in disease incidence and severity in this study is consistent with the findings of Chang *et al*. (2007) that organic manure enhanced vigorous growth in plants which increased the resistance threshold with a corresponding decrease in the rate of susceptibility to diseases

Effect of treatments on growth and yield of rice plants inoculated with *Magnaporthe oryzae*

The various growth parameters responded differently to all the treatments. Rice plants treated with T14 (*T. asperellum*, cattle dung and Blastforce fungicide} had the best overall growth performance with 27.0 tillers and reaching a height of 57.3 cm at the vegetative stage compared to treatment T_4 which served as the positive check (Table 2). This was followed by treatment T_{12} (*M. oleifera* extract, cattle dung and Blastforce) with 23.3 and 56.6 cm tillers and height respectively.

However, inoculated plants that were treated with a combination of *T. asperellum, M. oleifera* and cattle dung produced the highest yield of 7.6 tonnes/ha^{-1}, which was significantly higher than the control, followed by treatment with combined application of cattle dung and Blastforce (Table 3).

Table 2. Effect of *Moringa oleifera* extract, *Trichoderma asperellum*, Blastforce fungicide and cattle dung amendment on growth of rice

Treatment	No. of leaves	No. of tillers	Plant height (cm)	Root dry weight (g)	Shoot dry weight (g)
Plants inoculated with pathogen only (Control) (T_0)	43.3b	16.3b	55.8ab	7.3a	15.0ab
T. asperellum (T_1)	46.0b	19.3ab	42.8bc	6.5ab	11.9b
M. oleifera (T_2)	42.3b	16.7b	46.6b	5.6ab	11.5b
Cattle dung (T_3)	57.7a	23.0ab	47.9b	5.5b	15.0ab
bastforce (T_4)	43.3b	20.7ab	44.0b	4.8b	11.7b
T. asperellum+ *M. oleifera* (T_5)	50.0ab	20.7ab	53.7ab	4.9b	13.4ab
T. asperellum+cattle dung (T_6)	54.7a	22.7ab	50.1ab	6.2ab	19.0a
T. asperellum+Blastforce (T_7)	49.7ab	21.0ab	54.1ab	5.3b	14.5ab
M. oleifera + cattle dung (T_8)	51.0ab	22.0ab	51.8ab	5.8ab	11.8b
M. oleifera +Blastforce (T_9)	37.3bc	15.0b	47.8b	4.8b	13.7ab
Cattle dung + Blastforce (T_{10})	51.3ab	20.7ab	50.9ab	5.1b	15.4ab
T. asperellum + *M. oleifera* + cattle dung (T_{11})	44.3b	18.7ab	45.6b	7.6a	17.3ab
M. oleifera + cattle dung + Blastforce (T_{12})	58.0a	25.3a	56.5a	7.1a	16.0ab
T. asperellum+ blastforce + *M. oleifera* (T_{13})	51.7ab	23.0ab	45.8b	5.8ab	17.1ab
T. asperellum + cattle dung + Blastforce (T_{14})	61.7a	27.0a	57.3a	6.8ab	18.4ab
M. oleifera + cattle dung + Blastforce (T_{15})	40.0b	17.3b	43.3bc	5.4b	15.8ab
S.E	1.5	0.8	1.3	0.3	1.5
CV (%)	3.88	9.6	5.7	2.9	6.3

Means with the same letter along a column are not significantly different according to DMRT at $P \leq 0.05$.

Table 3. Effect of *Moringa oleifera* extract, *Trichoderma asperellum*, Blastforce fungicide and cattle cattle dung amendment on rice yield

Treatments	No. of panicles	Grain wt (g)	100 grain wt (g)	Grain yield (t/ha^{-1})
Inoculated and untreated rice plants (Control (T_0)	6.0ab	22.8d	4.1	4.3b
T. asperellum (T_1)	7.3ab	23.0d	4.0	6.5a
M. oleifera (T_2)	8.0ab	18.6d	4.0	5.6ab
Cattle dung (T_3)	11.7a	38.4ab	4.1	5.5ab
Blastforce (T_4)	8.0ab	28.5c	4.4	4.8b
T. asperellum + *M. oleifera* (T_5)	7.7ab	29.3c	4.2	4.9b
T. asperellum + cattle dung (T_6)	9.3a	36.5b	4.1	6.8a
T. asperellum + Blast force (T_7)	7.7ab	29.6c	4.1	5.3ab
M. oleifera + cattle dung (T_8)	9.0a	32.0bc	4.1	5.8ab
M. oleifera + Blastforce (T_9)	6.7ab	18.1de	4.0	4.8b
Cattle dung + Blastforce (T_{10})	9.0a	35.4b	4.1	5.3ab
T. asperellum+ *M. oleifera* + cattle dung (T_{11})	10.7a	34.9b	4.3	7.6a
M. oleifera + cattle dung+ Blastforce (T_{12})	8.7ab	25.2cd	4.0	7.1a
T. asperellum + Blast force + *M. oleifera* (T_{13})	8.7ab	32.7bc	4.0	5.8ab
T. asperellum + cattle dung + Blast force (T_{14})	11.7a	41.5a	4.2	6.2ab
T. asperellum + *M. oleifera* + CD + Blastforce (T_{15})	7.0ab	38.2ab	4.1	5.4ab
S.E (±)	0.5	1.2	0.1	0.7
CV (%)	4.4	7.8	1.2	3.6

CD = Cow dung. Means with the same letter along a column are not significantly different according to DMRT at $P \leq 0.05$

Treatments T_{11} and T_{12} with cattle dung combinations produced the highest grain yield per hectare. Organic manure has been reported to improve soil structure, enhance better aeration, and provides essential nutrients for plant growth (Chang *et al*., 2007). Cattle dung is an important source of bio-fertilizer, which enhances soil fertility and stimulates the activities of beneficial soil microbes with an overall increase in yield and the essential nutrients released from cattle dung such as phosphorus and potassium uptake had also been reported to increase yield and yield components (Andi and Nur, 2013). Previously, the application of cattle dung, *T. harzianum* and neem extract in various combinations has been found to be more effective in the management of bacterial blight disease of cowpea than treatment with single application of synthetic bacteriomycin (Dania and Oni, 2019).

Treatment combinations with *T. asperrellum* also significantly influenced rice growth and yield in this study. This is consistent with previous findings of Ritika and Utpal (2014) that *Trichoderma* species rapidly proliferated in the rhizosphere, thereby enhancing growth, development, crop productivity, resistance to abiotic stress, and the assimilation and utilization of nutrients by plants. Similarly, Harman (2006) and Faheem *et al*. (2010) reported that crop yield in fields could increase significantly after the addition of *Trichoderma* species, especially when seeds were previously treated with *Trichoderma* spores before planting in the field

Trichoderma asperellum had been reported to enhance optimization of available nutrients in the soil and thus was a good bio-stimulator of plant growth improving crop yield (Lopez-Bucio*et al*., 2015).

Plants inoculated with the pathogen and treated with a combination of *M. oleifera* extract, cattle dung and Blastforce had significantly lower disease incidence and mean severity. Integrated management of rice blast disease using the combination of *T. asperellum,* cattle dung and blastforce significantly increased the number of leaves, tillers, panicles and grain weight which were the major determinants of good crop yield. Therefore, the combined application of naturally occurring biopesticides and cattle dung along with a synthetic fungicide is strongly recommended in the management of rice blast disease.

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ANALYSIS OF FARMERS' KNOWLEDGE AND ATTITUDE TOWARDS LAC CULTIVATION IN BANGLADESH

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Abstract

The study was a descriptive survey, which was undertaken to describe the lac grower's knowledge and attitude towards lac cultivation. The study was conducted at two lac growing area of Naogan and Chapainawabganj district. Sixty lac farmers were selected randomly from selected area and considered as sample of the study. The interview schedule was developed according to the objective of the study. The farmer's knowledge on lac cultivation was calculated by answering 10 questions related to lac cultivation. Five point likertscale was employed to judge 15 attitude measuring statements towards lac cultivation. The highest proportion (36.67%) of the respondent was in 50%and above knowledge category but no respondent was found at 80% and above knowledge category. Maximum (86.67%) respondents possessed moderately to highly favourable attitude towards lac cultivation where only13.33% possessed less favourable attitude. Among the socio demographic characteristics**,** training exposure showed significant positive relationship with farmer's knowledge and attitude where education showed significant positive relationship with farmer's knowledge. Different need based lac cultivation related training to farmer can play vital role for development and popularization of lac cultivation.

Keywords: Lac cultivation, farmer's knowledge, farmer's attitude, assessment, lac growing area.

Introduction

Lac is the resinous substance secreted as a protective coating by the tiny lac insect, *Kerrialacca* (Kerr). It is one of the most valuable gifts of nature to manwhich is found as parasite on a number of both wild and cultivated plants (Anon., 1972). Lac is a complex mixture of resinous substances. Faruq *et al.* (1990) considered it as unparallel to any synthetic resin due to its unique combination of chemical, mechanical, thermal and electrical properties. Very small red coloured nymphs of the lac insect settle on the young succulent shoots of the host plants and suck the plant sap till the completion of their life cycle and death. Female lac insects secret a thick resinous fluid which covers their bodies.

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The secretion from the individual insect coalesces to form a hard continuous encrustation over the infested twigs of the host plants (Sengupta, 1972).

Lac insects can be cultured over a fairly wide range of the tropics and sub-tropics and on a large number of host trees (Anon, 1995). About 70% lac of the world is produced in India and they capture the highest position in the production and export of raw lac and lac products at the world market. Thailand is the second largest lac exporter after India with about 35% of the world market (Chuntanaparb, 1985). Lac has been cultivated in about three hundred hectares of land annually in Bangladesh from which is provide 180 tons of crude lac (Alam and Sarker, 2000). It has been reported that currently national production of lac is around 700 tonnes per year while the demand is estimated of about 15 times of that quantity (Mustafa, 2002).

Lac is cultivated in Bangladesh at Rajshahi division from many years (North-west part of Bangladesh). It was very popular and profitable crop at Rajshahi, Chapainawabganj and Naogaon district. Available host plants of Chapainawabganj district, has the capacity to produce 500 tons of raw lac which has a market value of Tk.40000000 and can provide job facilities to 20,000 landless and marginal farmers (Sarker *et al.*,2014).Though the lac cultivation and its marketing aspect have a tremendous prospect on the socio-economic development of the rural poor people of the country, but gradually then umber of families involved in lac growing activities are decreased with time which is very much alarming (Ferdousee *et al*., 2010). Several difficulties may be involves behind the present situation of lac cultivation. The research work is also very scanty to identify the present problem of lac production in Bangladesh. In this situation lac farmer's knowledge and attitude assessment study will help to identify the socio-economic and technical problem of lac cultivation. The present study will also help to develop exact policy for improved lac production. Therefore, the present study has been designed to evaluate lac grower's knowledge and attitude towards lac cultivation.

Methodology

The study was a descriptive survey, so an interview schedule was used to describe the lac grower's knowledge and attitude towards lac cultivation. Two Unionsnamely Kasba from Nachole Upazila of Chapainawabganj district and Niamatpur from Niamatpur Upazila of Naogaon district were selected as the study area on the basis of availability of the villages and respondents involved in lac cultivation. There was no exact information about the number and location of lac farmer at selected area. So for reducing time and cost thirty lac farmers were selected randomly from each of the selected Union and total sixty farmers was considered as the sample of the study.

The interview schedule was divided into two parts: (a) personal and professional characteristics of the farmers and (b) their viewpoint (knowledge, attitude) towards lac cultivation and at this part 10 knowledge measuring questions and 15 attitude measuring statements were employed. Five points Likert scale was used to judge the attitude towards lac cultivation. Data were collected from the selected farmers by face to face interview method.

Measurement of dependent variable

The farmer's knowledge and attitude towards modern lac cultivation were the dependent variable of this study. The farmer's knowledge on lac cultivation was calculated by answering 10 questions aboutlac cultivation. The assigned score against each correct, partially correct and incorrect answer was 2, 1, and 0, respectively. Thus, one's Knowledge on lac cultivations cores could ranged from 0 to 20, where '0' indicating 'no knowledge and '20' indicating very high knowledge'. Based on knowledge score, the respondents were classified into the following categories.

Farmer's Categories	Knowledge Score
80% and above having correct knowledge on lac cultivation	16 and above
70% and above havingcorrectknowledgeon lac cultivation	14 and above
60% and above havingcorrectknowledge on lac cultivation	12 and above
50% and abovehavingcorrectknowledge on lac cultivation	10 and above
40% and above havingcorrect knowledge onlac cultivation	8 and above
less than 40% havingcorrect knowledgeon lac cultivation	less than 8

Meanwhile, fifteen opinion statements were administered for judging the farmers attitude towards lac cultivation.The farmers were asked to indicate the extent of their agreement on each of the 15 statement utilizing a Likert-type fivepoints scale like strongly agree, agree, undecided, disagree and strongly disagree with assigned scores of 5, 4, 3, 2 and 1, for positive statements, respectively and vice versa for negative statements. By adding together the assigned scores of 15 statements of a respondent, the attitude of a farmer towards lac cultivation was measured and categorized into the following three categoriesbased onmean and standard deviation score.Hasan*et al.*(2015)also classified farmer's attitude into three categories.

Categories	Score
Less favourable attitude	Up to50
Moderately favourable attitude	51 to 60
Highly favourable attitude	over 60

The attitude measuring statements score and rank were calculated by adding individual statements score from total 60 interview schedulefollowing Hasan*et al.*, 2015.

Measurement of independent variables

There were four independent variables of thestudy and those were farmer's age, level of education, family annual income, and training experience on lac cultivation. Age of a respondent was measured by counting the years from the time of his/her birth to the time of interview. The level of education was measured by the number of years of schooling. Family annual income of a respondent was determined on the basis of his total earnings from agriculture, service, business, and other sources. Training experience on lac cultivation was measured by respondent's training experience on lac cultivation in his entire life from different organizations. The assigned score for having training experience is 1 and for not having training experience is 0.

Statistical Analysis

Statistical Package for Social Science (SPSS) version 21 was used for analysing the data of this study. To achieve the objectives of the study the mean, standard deviation were calculated and different categories were used for classifying the data. Different statistical tests like frequency count, percentage, mean, standard deviation were applied to analyse and interpret the data based on the purpose of the study. The degree of relationship between dependent and independent variables were determined by calculating the Coefficient of Correlation (r).

Results and discussion

Knowledge on lac cultivation

Knowledge scores on lac cultivationof the respondent ranged from 7 to 14, with an average was 10.5. The respondents based on their knowledge scores on lac cultivation were classified into six categories as shown in Figure 1.

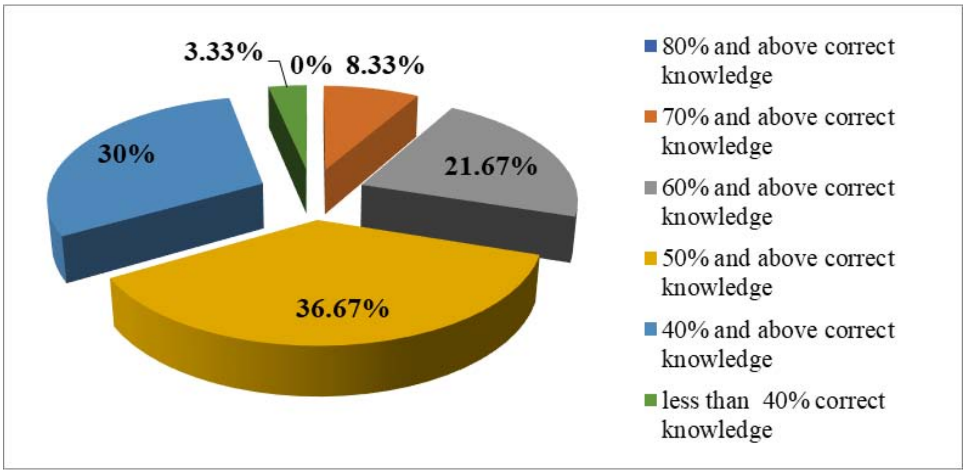

Fig. 1. Distribution of the respondents according to their knowledge on lac cultivation.

Figure1 indicated that the highest proportion (36.67 %) of the respondents were in 50%and above knowledge category while 30 % respondents fell into 40%and above knowledge category. But no respondents were found 80% and above knowledge category. So there are opportunities to increase the lac cultivation related knowledge of the respondents. Better knowledge on lac cultivation will be helpful to make the farmer more efficient and confident.

Score of knowledge measuring questions

Table 1 indicated that respondents had top most knowledge in answering the question 'Name two host plant of lac' where the total score was 118out of 120 followed by answer of the questions 'Mention two uses of lac' (score= 109), 'Which is the suitable time for Baishakhi and kartiki lac harvesting?' (Score = 100), respectively. The question 'Name two fungicides that can be used against lac crop infesting disease.' was at 10^{th} rank with 11 score. That means farmer's response was most correct when they were asking about general aspect of lac cultivation but their response was less correct when they were asked about modern technique to improve the lac production. Entomology division, Bangladesh Agricultural Research Institute, Gazipur and Lac research station, Chapainawabganj has developed some modern lac cultivation technology (Sarker *et al.*,2014) but most of the farmer didn't know about it. Agriculture Extension Department can play role to disseminate this technology to the farmer. Training, workshop, seminar etcon modern lac cultivation technology for researcher, extension worker and farmer would be helpful to improve the situation in the study area.

Table 1. Distribution of the individual knowledge measuring questions according to their score and rank order

SL No	Questions	Score	Rank
01	Name two host plant of lac.	118	1
02	Mention two uses of lac.	109	2
03	Which is the suitable time for Baishakhi and kartiki lac harvesting?	100	3
04	Name two crops which can be used as inter crop with lac.	98	4
05	Mention the suitable time for pruning of host plant for Baishakhi and kartiki lac cultivation.	86	5
06	Name the steps of lac processing	56	6
07	Name two predator of lac insect	25	7
08	Name two bio-pesticides that used against lac insect pest.	21	8
09	Mention two techniques to preserve moisture in Baishakhi lac season.	15	9
10	Name two fungicides that can be used against lac crop infecting disease.	11	10

Attitude towards lac cultivation

Farmer's attitude towards lac cultivation scores ranged from 45 to 72, with an average of 55.22. The respondents based on attitude on lac cultivation scores were classified into three categories (Table 2). It was found that 76.67% of the respondents possessed moderately favourable attitude towards lac cultivation, 10% possessed highly favourable attitude and13.33% possessed less favourable attitude (Table 2). There were lot of scope to improve farmer's attitude towards lac cultivation. Education, training and awareness building activity would help the farmer to gain knowledge and help them to become rational and in turn increases their attitude. Friendly policy of lac production might improve the attitude of the farmer towards profitable lac cultivation.

Table 2. Distribution of the lac farmer according to their attitude towards lac cultivation

Categories	respondents	%	Mean	Standard Deviation
Less favorable attitude (up to 50)	8	13.33		
Moderately favorable attitude (51-60)	46	76.67		
Highly favorable attitude (over 60)	6	10	55.22	4.78
Total	60	100		

Table 3. Distribution of the individual attitude measuring statements according to their score and rank order

SL No	Statements	Score	Rank
01	Lac cultivation require less chemical fertilizer and water (+)	282	1
02	Insect and Pest attack is minimum in lac cultivation (+)	262	2
03	Lac cultivation ensure best use of local resource (+)	260	3
04	Lac cultivation is not harmful for host plant (-)	256	4
05	Lac cultivation is a good way to income generate for the ultra poor persons (+)	252	5
06	Lac cultivation is laborious and it reduce prestige (-)	250	6
07	Host plant is not available for lac cultivation (-)	236	7
08	Lac cultivation creates working opportunity for women and youth (+)	231	8
09	I am willing to establish in this profession and like to obtain more knowledge for my own sake (+)	229	9
10	Inter cropping is possible in lac cultivation (+)	221	10
11	Lac cultivation is less expensive compare to other crop cultivation (+)	207	11
12	Lac production, processing and marketing technique is very difficult (-)	203	12
13	Lac cultivation give maximum return with minimum input (+)	185	13
14	Pesticide spray in mango field causes less production of lac (-)	132	14
15	Market price of lac is very low (-)	107	15

Score of attitude measuring statements

The attitude measuring statements about lac cultivation are presented with their score and rank in Table 3. It was observed that, "Lac cultivation require less chemical fertilizer and water" this statement ranked first with the score of 282 followed by statement, "Insect and Pest attack is minimum in lac cultivation", score, 262. Statement, "Lac cultivation ensure best use of local resource", ranked 3rd and its score was 260. 'Market price of lac is very low', was at 15th rank with 107 score. Though farmer's showed very much positive attitude towards different environmental and social issues of lac cultivation but they were anxious about economic return from lac cultivation.

Farmers' demographic characteristics

Four socio-demographic information of the farmers like age, educational qualification, annual income, training received are presented in Table 4. The Table provided categories, frequencies, and percentage for all these demographic variables and indicated that most of the farmers (50%) were in 30 to 40 years of age compared to 26.67% were between 41 to 50 years. From the present study it was found that 56.67% of the respondents were educated either in primary, secondary or tertiary level but 43.33% of the respondents had no education. The average income of the respondents of the study area was Tk.83450.00 which was lower than the national average of Tk.96256 (1203.20 USD) (Trading Economics, 2018). Most respondentsof the study area(83.33%) had no training exposure on lac cultivation.

Table 4. Demographic characteristics profile of the farmers (n= 60)

Variable	Categories	Frequencies	%
Farmer's Age (Mean = 38.62, SD ± 08.06)	Less than 30 years	9	15
	30 to 40 years	30	50
	41 to 50 years	16	26.67
	51 to 60 years	5	8.33
	More than 60 years	0	0
Level of education (Mean = 3.30, SD ± 3.42)	No education/illitarate	26	43.33
	Primary education	23	38.33
	Secondary (SSC level)	9	15
	Upper SSC level	2	3.33
Family annual income [Mean = 83450.00 BDT (1043 USD)]	Less than 50000 BDT	4	6.67
	50000 to 70000 BDT	31	51.67
	More than 70000 BDT	25	41.67
Training participation on lac cultivation	No training	50	83.33
	Training	10	16.67

Source: Surveyed data collected by the author's in this study

Results indicated that most of the respondents were middle aged person and many of them were illiterate. Middle aged person has good working ability but they need proper educationto improve their observation, analysis, integration, understanding, decision making and adjustment to new situation. Respondent's training experience was also very poor. Different GOS and NGOS can play a vital role to strengthen their services in this regard.

Relationship between the selected characteristics of the respondents and their Knowledge and attitude towards lac cultivation

PearsonsCorrelation Co-efficient "r" has been used to determine the relationships between the selected demographic characteristics of the respondents and their knowledge and attitude towards lac cultivation. Training exposure showed significant positive relationship with farmers' knowledge and attitude where education showed significant positive relationship only with farmers' knowledge.Others relationships were non-significant (Table 5). So, farmers' knowledge and attitude will increase with the increase of training program.

Table 5. Relationship between demographic characteristics of the farmer and their knowledge and attitude towards lac cultivation

Selected characteristics of the respondents	Coefficient correlation value of 'r'	
	Knowledge	Attitude
Age	- 0.030	- 0.195
Education	0.404**	0.203
Annual income	0.146	0.039
Training exposure	0.568**	0.422**

** Correlation is significant at 1% level

Conclusions and Recommendations

The present study assessed the farmers' knowledge and attitude towards lac cultivation at lac growing area of Bangladeshi.e, Naogan and Chapainawabganjdistricts. Findings exhibited that most of the farmers (91.67%) in this study were below 51 years of age, while about 56.66% of them were educated either primary, secondary or more. The average family annual income of the farmers was 1043 USD which was lower than the average national income of the Bangladesh (1203.20 USD). Most of the farmer (83.33%) did not receive any training on lac cultivation and related issues. Meanwhile, 58.34% of them had 50- 70% correct knowledge on lac cultivation. About 90% of the farmers maintained moderately to less favorable opinion towards lac cultivation. Farmers training participation on lac cultivation had an influence on their knowledge and attitude towards lac cultivation. Thisfindings indicate that higher level of training exposure will result higher knowledge and attitude towards lac cultivation. The farmers should be provided with different types of need-based training related to lac cultivation. Hence, the government and non-government organization should take proper steps in this regard.

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EFFECT OF PLANTING DATES ON PERFORMANCE OF BROCCOLI IN COSTAL AREA OF BANGLADESH

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Abstract

The field experiment on broccoli (*Brassica oleracea var. italica* L.) taking three planting dates *viz*., 21 November, 01 December and 11 December, 2019 and four genotypes, namely BARI Broccoli-1, Thiland-1, Thailand-2 and Japan-1 was conducted during *rabi* season of 2019-20 in the experimental field of Bangladesh Agricultural Research Institute, On-Farm Research Division, Dawlatpur, Khulna to investigate the effect of planting dates on the growth and yield of broccoli genotypes on saline soil having salinity level 2.6-4.8 dS/m . The experiment was laid out in 4 x 3 factorial randomized complete block design with three replications. The genotype Japan-1 gave maximum number of leaves/plant (25.44), fresh weight of leaves/plant (830.77 g), fresh weight of stem/plant (311.69 g), fresh weight of root/plant (53.47 g), which were not reflected into yield and yield attributes. The genotype Thailand-2 produced significantly lower all growth characters than those of Japan-1 but gave the highest curd diameter (18.11 cm, curd weight (360.19 g) and curd yield (16.01 t/ha) of all genotypes. Broccoli planted on 21 November initiated early flower head, recorded maximum number of leaves/plant (27.84), fresh weight of leaves/plant (800.87 g), fresh weight of stem/plant (313.73 g), fresh weight of root/plant (60.79 g), curd diameter (17.01 cm), curd weight (285.65 g) and curd yield (12.69 t/ha). The genotype Thiland-2 coupled with 21 November showed the best performance in respect of curd weight (419.74 g/plant) and curd yield (18.66 t/ha).

Keywords: Broccoli, genotype, planting date, curd yield. Coastal area, Bangladesh.

Introduction

Broccoli (*Brassica oleraceavar. italica* L.), an important member of "Cole" crops, belongs to the family *Brassicaceae*. Broccoli originated from west Europe (Prasad and Kumer, 1999). The word "Cole" means a group of highly differentiated plants originated from a single wild *Brassica oleracea var. oleracea* (Sylvestris L.) commonly known as wild cabbage (Bose and Som, 1986). Broccoli is grown in winter season in Bangladesh as an annual crop. It is environmentally better adapted and can resist comparatively high temperature

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than cauliflower (Rashid *et al.,* 1976). Its wider environmental adaptability, higher nutritive value, good taste and less risk to crop failure are due to various biotic and abiotic factors indicate that there is enough possibility for its promotion. Its popularity to the consumers of urban area is increasing day by day in our country but its cultivation has not spread much beyond the farms of different agricultural organizations. This is mainly due to the lack of awareness among the people about its importance and inadequate information production technology. Cultivation of broccoli are confined into a very limited area with its average yield is only about 10.5 metric tons per hectare (Anonymous, 2004) which is very low compared to other broccoli growing countries like 24 t/ha in Italy, 20 t/ha in Japan and 18 t/ha in Turkey (Ahmed *et al.,* 2004).

Bangladesh is a deltaic country with total area of 147570 km^2. Coastal area includes 30% of the cultivable land in Bangladesh. About 10 lakh hectares (1m. ha) of land are affected by varying degrees of soil salinity (Karim and Iqbal, 2001). After harvesting of T. Aman rice a remarkable area of land remains fallow in this region. Again, during *rabi*season, soil salinity level increases through capillary movement. Which constraint for *rabi* crops in saline coastal region.

The planting dates have significant effect on yield and yield contributing characters of broccoli plant. The yield decreased with delay planting time. Curd yield is higher when crops are planted earlier and show a decreasing trend with delay in planting dates (Bianco*et al.,* 1996). Early planted crops resulted in longer duration and produced taller plants with more number of leaves, higher plant spread and more leaf size index as well as the lowest percentage of abnormal curds than late planted crops and finally attributed to higher curd yield (Gautam*et al.,* 1998). So, there is enough scope to identify the optimum planting date to maximize the broccoli yield. Broccoli genotypes have also significant effect on yield of broccoli. Cultivar "Captain" produced the highest total yield as well as top and lateral head yields, the largest top head weight and marked earliness which was followed by cultivars Lucky, General, Griffen, Liberty and Milady (Toth*et al.,* 2007). Several broccoli genotypes are cultivated in our country those differ in yield. So, it is essential to identify high yielding genotypes to maximize broccoli yield. Therefore, the present experiment was undertaken to find out optimum planting date and suitable genotype for maximum yield of Broccoli.

Materials and Methods

This experiment was conducted during 21November 2019 to 25 February 2020 in the experimental field of Bangladesh Agricultural Research Institute, -Farm Research Division, Dawlatpur, Khulna. The location of the experimental site was at High Ganges River Flood Plain (22.8875 N latitude and 89.5167E longitudes). The soil of the experimental field was Silt loam-Clay of dark grey soil color. The soil contained pH of 6.8 and organic matter 2.1 %. The experiment consists of three planting dates *viz*., 21 November, 01 December and 11 December, 2019 and four genotypes, namely BARI Broccoli-1, Thiland-1, Thailand-2 and Japan-1. Thiland-1, Thailland-2 and Japan-1 were collected from the market of Dhaka and BARI Broccoli-1 was collected from Bangladesh Agricultural Research Institute, Gazipur. The field experiment was laid out in a factorial Randomized Complete Block Design with three replications. The unit plot size was 4m x 1.5maccommodating 24 seedlings/plot. The land was fertilized with nitrogen, phosphorous, potassium and molybdenum as cowdung, urea, TSP, MoP and molybdenum @ 1500, 210, 120, 100 and 1kg/ha, respectively. The entire amount of Cowdung, TSP, MoP and Molybdenum were applied at the time of final land preparation and the entire urea was applied as top dressing in two equal split at 15 and 30 days after transplanting (DAP). Seeds were treated by provax @ 2 g/kg seed. Treated seeds were sown in seedbed on 28 October, 7 November, and 17 November 2019. Healthy 25 days old seedlings were transplanted on 21 November, 01 December and 11 December 2019. Weeding was done 6 times to keep the plots free from weeds and the soil was mulched by breaking the soil crust for easy aeration and conservation of soil moisture. The plots were irrigated four times at regular interval during the growth season to keep the field moist for better growth and development of plant. Five broccoli plants from each plot were selected randomly for collecting data. The plants of the outer rows and the extreme end of the middle rows were excluded from data collection. Data on number of leaves/plant, fresh weight of leaves. plant (g), fresh weight of stem (g)/plant and fresh weight of root (g)/plant, curd weight (g)/plant, curd diameter)cm) and curd yield (kg)/plot were recorded. Plot yield was converted to per hectare yield (t/ha).Soil salinity of the experimental plots was recorded in every 15 days interval from planting to harvesting of the crop (Fig. 1). Soil salinity was varied from 2.5 to 4.8dS/m. No diseases and insect attack were observed in the broccoli experiment. Collected data were statistically analyzed by Software R (version 3.5.1). Mean separation was done by LSD at 5% level of significance.

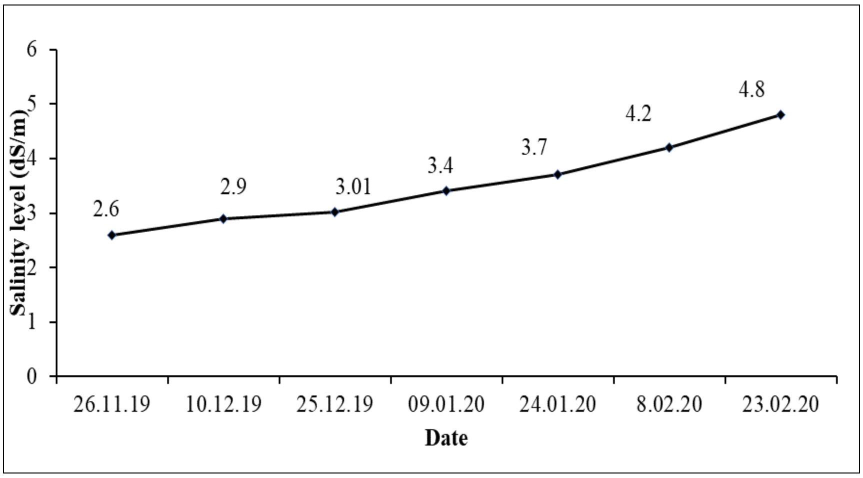

Fig. 1.Salinity level of experimental field during crop growing period.

Results and Discussion

Morphological characters of different genotypes

Number of leaves/plant

The highest number of leaves (25.44) was recorded from the genotype Japan-1 as compared to that of Thailand-1 and Thialnd-2 were (23.56 and 20.44, respectively)(Table 1).. The lowest number of leaves (15.44) was obtained from BARI Broccoli-1. Variation in number of leave/plant may be due to the difference in genetic make-up of broccoli genotypes0Significant variation in number of leaves/plant was observed due to different planting dates (table 2). The highest number of leaves/plant was obtained from 21 November planting (27.84). The lowest number of leaves/plant was recorded from01 December (17.67) which was statistically similar to 11 December (18.17).

The highest number of leaves/plant (35.67) was recorded from the genotype Japan-1 when planted on 21 November and the lowest number of leaves (13.33) was obtained fromV_1T_2 (BARI Broccoli-1when planted on 11 December and it was statistically similar with V_2T_3, V_3T_2, V_4T_3, respectively. Number of leaves/plant varied from82.67 to 13.33 (Table 3).

Maximum number of leaves/plant by 21 November was might be due to the optimal environmental conditions in the field. The most suitable temperature range for good quality and yield of broccoli is 19.22°C. When seedlings were transplanted in the field, average temperature remained near about 19.22°C during growth, whereas, 7 December availed comparatively lower temperature (8-14^{0}C) during growth period. The result of the present study was similar to Jamil *et al.*, (2004) who found significantly variation in T_3 (15 November) produced maximum leaves per plant. Shapla *et al.*, (2014) and Emam (2005) also reported that early planting increased number of broccoli leaves per plant.

Fresh weight of leaves/plant

There were significant differences among the genotypes in respect of fresh weight of leaves/plant. The highest fresh weight of leaves/plantwas recorded from Japan-1 (830.77 g) which was significantly different from other genotypes and the lowest was obtained from BARI Broccoli-1 (395.56 g).Leaf fresh weight represent leaf biomass (Table 1).

Fresh weight of leaves of broccoli varied significantly with planting dates (table 2). Maximum fresh weight of leaves/plant was obtained from 21 November planting (800.87 g) followed by 01 December planting (448.99 g) and the lowest fresh weight of leaves/plant was recorded from 11 December planting.

The combined effect of genotypes and planting dates was found significant in respect of fresh weight of leaves/plant (table 3). The highest fresh weight of leaves/plantwas obtained from V_4T_1 (Japan-1 planted on 11 November) (1566.46

g). The minimum fresh weight of leaves/plant was obtained from V_3T_3 followed by V_3T_2, V_1T_3, V_1T_1, V_4T_3, respectively.

Since the early planting recorded more number of leaves per plant which has direct relation with fresh weight of leaves. Emam (2005) and Shapla *et al.*, (2014) also reported similar findings. Getachew (2016) also observed significant variation in fresh weight of leaves of Broccoli.

Fresh weight of stem/plant

The genotype Thiland-1 produced the highest weight of stem (356.78 g) and the genotype BARI Broccoli-1 gave minimum fresh weight of stem (137.05 g) (Table 1).

Significant variation in fresh weight of stem was observed due to the influence of planting dates (Table 2). Broccoli planted on 21 November produced the maximum fresh (313.73 g) weight of stem. Minimum fresh weight of stem was found from 11 December planting (214.68 g) which was statistically similar to that of01 December planting (Table 2).

There were significant differences in fresh weight of stem due to interaction of genotypes and planting dates (table 3). This study showed that late planting of seedling lead to weight loss of stem. The highest fresh weight of stem was obtained from V_2T_1 (Thiland-1 planted on 21 November) (435.23 gm). Treatment combinationV_1T_3 and V_1T_2 showed the lowest fresh weight of stem

Fresh weight of root/plant

The highest fresh weight of root (53.47 g) was recorded from Japan-1 (Table 1). The genotypes Thiland-1(44.31 g) and Thiland-2 (46.59 g) gave statistically similar weight and the lowest weight was recorded from BARI Broccoli-1 (33.20 g) (Table 2).

The 1st planting 21 Novemberpr0ducedthe highest fresh weight of root (60.79 g) (table 2). There was trend to decrease root weight with the advisement of date where the lowest from 01 December followed by 11 December.

The highest fresh weight of root was obtained from V_4T_1 (81.06 g) which was statistically similar to V_3T_1 (72.47 g). The lowest fresh weight of root (29.52 g) was obtained from V_3T_3 (Table 3). Getachew (2016) observed significant variation fresh weight of root of Broccoli. At early planting fresh weight of root was (35.7 g) and late planting was (15.3 g)

Curd initiation

Genotypic differences were observed on days to curd initiation (Fig. 2). BARI Broccoli-1 required minimum number of days 67, 69 and 72, respectively for first curd initiation, 50% curd initiation and total curd initiation while these were maximum in Thiland-2, which were 73, 76 and 84 days, respectively. Similar results were obtained in broccoli by Hafiz *et al.*, (2015) who reported that early planting (2 October) curd initiation was 89.3% than the late planting (16 December) where curd initiation was 75.3% .

Curd initiation was varied due to planting date (Fig. 3). It was revealed that 67 days for first curd initiation was required in 21 November planting which showed a decreasing trend with the advancement planting. Similar trends were also observed in 50% curd initiation and 100% curd initiation. In both cases maximum number of days 70 and 73 were required for 50% and 100% curd initiation, respectively in 21 November planting, which decreased to 55to 58 days in 01 December planting. Curd formation in broccoli was quite similar to the curd formation of cauliflower which was primarily influenced by temperature. When broccoli sown late then it was exhibited premature head initiation i.e., curd initiation started before completion of vegetative growth.

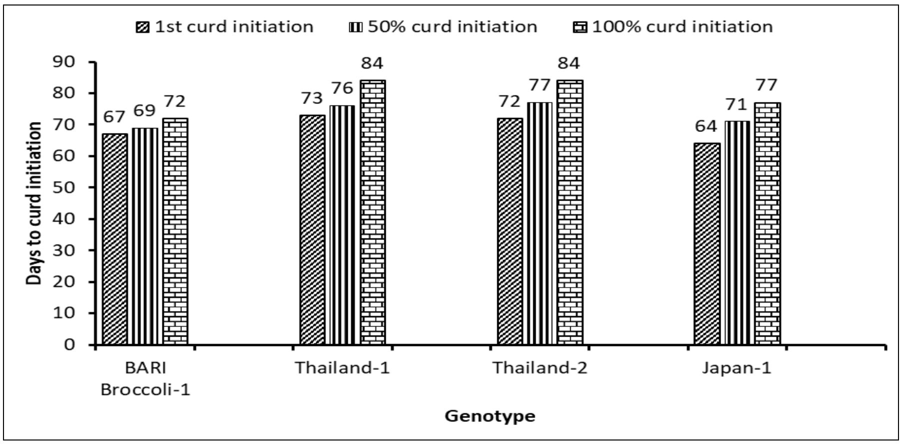

Fig.2. Genotypic differences on days to curd initiation in broccoli.

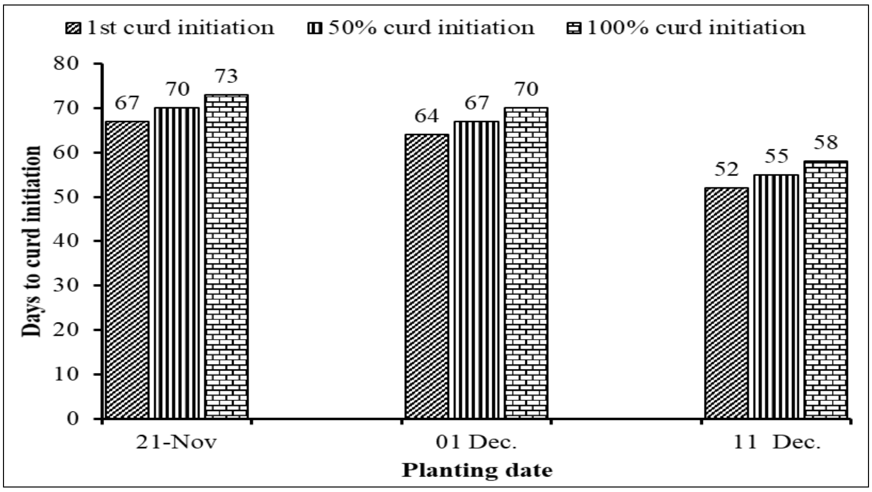

Fig. 3. Effect of planting dates on days to curd initiation in broccoli.

Curd diameter

Diameter of curd significantly varied among the genotypes and the interaction between genotypes and planting dates. The highest curd diameter was obtained from the genotype Thiland-2 (18.13 cm) while genotype Japan-1 (15.34 cm), statistically identical with Thiland-1 (15.94 cm) and BARI Broccoli-1 (16.46 cm) (Table 1).

Significant difference was not found in planting date but early planting slightly higher in diameter of curd (17.01). The result was in agreement with the Hafiz *et al.*,(2015) who reported that transplanting of broccoli in early planting produced better head (Table 2).

The treatment combination V_3T_2 produced highest curd diameter (19.43cm), which was identical to V_4T_1 (19.33 cm), V_3T_3 (17.50 cm), V_3T_3 (17.47 cm) and V_2T_2 (17.33 cm) while it was minimum curd diameter was V_4T_2 (12.77 cm), V_4T_3 and V_2T_2 (Table 3).

Maximum performance of diameter of the curd might be due to more supply of photosynthates from the leaves. Besides early November planting obtained more leaf size, leaf length and number of leaves as compared to all other treatments while late planting showed the minimum diameter of the curd due to small size and number of leaves Jamil *et al.,* (2004) also reported similar finding.

Table 1. Effect of genotypes on growth, yield contributing characters and yield of broccoli

Genotypes	Number of Leaves /plant	Fresh weight of leaves/plant (g)	Fresh weight of stem/plant (g)	Fresh weight of root/plant (g)	Curd diameter (cm)	Curd weight (g/Plant)	Curd yield (t ha^{-1})
BARI Broccoli-1 (V_1)	15.44	395.56	137.05	33.20	16.46	215.01	9.81
Thiland-1 (V_2)	23.56	525.22	356.78	44.31	15.94	254.02	11.29
Thiland-2 (V_3)	20.44	423.44	198.11	46.59	18.13	360.19	16.01
Japan-1 (V_4)	25.44	830.77	311.69	53.47	15.34	251.33	11.17
$LSD_{(0.05)}$	3.58	146.69	24.36	5.94	1.36	35.60	1.43

Curd weight/plant:

Central curd weight was significantly influenced by the genotypes, planting dates and their interaction effects. The maximum weight was recorded from genotype

Thiland-2 (360.19 g) followed by the genotypeThiland-1 (254.02 g) which was statistically identical with Japan-1 (251.33 g) while it was minimum from BARI Broccoli-1.Srivastava (1960) reported that good curd depends on the number of leaves, their size (length and breadth) and ability to store carbohydrates and other nutrients within a particular temperature range (Table 1).

Curd weight varied significantly due to planting dates. The maximum curd weight (285.65 g) was found from 21 November planting, which was statistically identical with 01 December planting (276.65 g) and the minimum curd weight (248.13 g) was found from 11 December planting. This result was in agreement with the findings of Hafiz *et al.*,(2015)(Table 2).

Combined effect of genotype and planting dates curd weight differed significantly ranging from 146.36 g to 419.74 g (Table 3). The maximum curd weight (419.37 g) was recorded from V_3T_1 (Thiland-2 on 21 November) that was statistically identical withV_3T_2 (388.49 g) and V_4T_1. The minimum curd weight (146.37 g) was obtained from V_4T_2 (Japan-1 planted on 11 December) and V_2T_1. The plants under treatment combination V_3T_1 and V_3T_2 performed better because of prevailing suitable temperature for vigorous vegetative growth resulting in higher curd weight. Similar results were obtained by Bianco *et al.,* (1996) who reported that central curd yield was higher when crop planted earlier.

Table 2. Effect of planting dates on growth, yield contributing characters and yield of broccoli

Panting date	Number of leaves /plant	Fresh weight of leaves/plant (g)	Fresh weight of stem/plant (g)	Fresh weight of root/plant (g)	Curd diameter (cm)	Curd weight (g/plant)	Cird yield (t ha^{-1})
21 November (T_1)	27.84	800.87	313.73	60.79	17.01	285.65	12.69
01 December (T_2)	18.17	448.99	224.32	35.55	16.55	276.65	12.30
11 December (T_3)	17.67	381.38	214.68	34.83	15.85	248.13	11.22
$LSD_{(0.05)}$	3.10	127.03	21.10	5.14	NS	30.83	1.24

Curd yield

Significant variation in curd yield (t/ha) was observed among the genotypes. The highest curd yield (16.01 t/ha) was obtained from the genotype Thiland-2. This might be due to highest curd diameter and curd weight. The lowest yield (9.81 t/ha) was recorded from BARI Broccoli-1due to lower yield attributes (Table 1).

Planting dates also had significant influence on the yield of broccoli. Genotypes of 21 November planting produced the maximum curd yield (12.69 t/ha) followed by 01 December planting (12.30 t/ha). It might be due to favorable low temperature (10.8°C to 11.6°C) for the curd setting and development. On the other hand, minimum curd yield (11.22 t/ha) was obtained from 11 December planting. It might be due to comparatively higher temperature than the optimum at that time (Table 2). Interaction effect of genotypes and planting dates on yield per hectare was found significant (Table 3). The combination V_3T_1 produced the maximum curd yield (18.66 t/ha) which was statistically identical to V_3T_2 (17.27 t/ha) and V_4T_1 while the lowest curd yield was obtained from V_4T_2 (6.51 t/ha) which was statistically similar to V_1T_1 (7.82 t/ha) and V_2T_1 (7.84 t/ha).

Environmental factors such as light, temperature and rainfall played an important role in growth and yield of broccoli. As the light and temperature remained favorable for 7th November planting date ultimately more photosynthates were available for improvement of yield. The results are well in collaboration with the findings of Diputadeo *et al.*, (1989), Patil *et al.*,(1992), Swiader *et al.*, (1992) and on Cole crops. Similar results were obtained in broccoli by Hafiz *et al.*, (2015) who reported that early planting gave higher yield

Table 3. Interaction effect of genotypes and planting dates on growth, yield contributing characters and yield of Broccoli

Interaction (V×T)		Number of leaves /Plant	Fresh weight of leaves (g)	Fresh weight of stem (g)	Fresh weight of root (g)	Curd diameter (cm) /plant)	Curd weight (g/plant)	Curd yield (t ha^{-1})
	T_1	16.67	418.13	156.28	32.72	15.67	175.93	7.82
V_1	T_2	13.33	466.93	143.43	30.54	16.67	248.27	11.03
	T_3	16.33	301.55	111.44	36.31	17.03	220.76	10.56
	T_1	32.67	533.26	435.31	56.90	15.56	176.56	7.84
V_2	T_2	23.00	560.37	352.32	38.91	17.33	323.45	14.37
	T_3	15.00	482.01	282.71	37.10	14.93	263.05	11.65
	T_1	26.33	685.56	271.14	72.47	17.46	419.74	18.66
V_3	T_2	17.00	317.16	155.56	37.78	19.43	388.49	17.27
	T_3	18.00	267.59	167.63	29.51	17.50	272.34	12.10
	T_1	35.67	1566.46	392.19	81.06	19.33	370.29	16.46
V_4	T_2	19.33	451.49	245.95	40.09	12.76	146.36	6.51
	T_3	21.33	474.35	296.91	39.25	13.93	237.33	10.55
LSD (0.05)		6.22	254.07	42.19	10.66	2.37	61.66	2.37
CV (%)		14.377	27.59	9.93	13.47	8.50	13.47	8.50

V_1 = Broccoli-1, V_2= Thiland-1, V_3= Thiland-2, V_4= Japan-1

T_1=21 November, T_2=01 December, T_3=11 December

Conclusion

The results of the present experiment indicated that the ,genotypeThiland-2performed best among the studied genotypes and 21 November planting was found to be the optimum date of planting for Broccoli. So thegenotypeThiland-2 should be planted on 21 November for maximum curd yield of Broccoli in coastal area of Bangladesh..

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EFFECT OF AGRICULTURAL POLICY AND RESOURCE UTILIZATION ON SMALL-SCALE GROUNDNUT PRODUCTION IN NIGER STATE, NIGERIA

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Abstract

The present research empirically determined farm resource-input utilization among the groundnut farmers and the effect of agricultural policy on groundnut production in Niger State of Nigeria. A total of 120 farmers were selected through a multi-stage sampling technique. Thereafter, a structured questionnaire complemented with the interview schedule was the instruments used to elicit information from the respondents and the collected data were analyzed using inferential statistics and the policy analysis matrix (PAM). The empirical findings showed that groundnut production is affected by the failure of the farmers to apply the recommended inorganic fertilizer dosages. In addition, the farmers were not economically efficient as allocation of the farm inputs were not optimized. The farm size, seed, manure, biocides and depreciation on capital had an index of greater than 1.00 while NPK and human labour AEI index were less than 1.00. Furthermore, the agricultural policy was not in favour of the farmers despite the effort in deregulating the agricultural marketing sub-sector. Therefore, the study recommends that the extension agents should re-train the farmers on the appropriate technologies needed in the application of recommended dosage for agro-chemical, especially inorganic fertilizer. In addition, the government should improvise a protectionist policy for the producers so that they can compete favourable and earn remunerative prices in the agricultural commodity markets.

Keywords: Resources; Optimization; Farm; Policy; Groundnut; Nigeria

Introduction

In Nigeria, groundnut has become a major staple food in most homes today and unfortunately, the domestic production of groundnut has not met the demand thereby leading to food shortages (Sadiq *et al*., 2017). The food problem in the country has been exacerbated by a low level of productivity of resources used in recent times which leads to low profit. The gap between demand and supply of agricultural products in Nigeria has been on the increase since focus shifted away from agriculture to other sectors of the economy (Audu *et al*., 2017). This is not unconnected to challenges such as inefficient management, low capital base and inadequate information about new production technology.

In spite of Nigeria's fertile soils, large expanse of arable land as well as suitable climatic factors all of which favours groundnut production, the nation's output of the crop has declined over the years, thus losing its leading position to countries

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like China and the United States of America that have invested immensely in both institutional and market organizations that linked the farmers to markets (Table 1; Figure 1 and 2) (Yusuf, 2016).

Based on the increased population in the study area, there is a need to match the gap with food production because groundnut is an important crop for realizing this dream given its nutritional and industrial benefits. The crop has been a principal commodity produced by the majority of households in the study area; hence, output increase of groundnut is an important step towards achieving self-sufficiency of the crop in the study area.

Given the above scenario, it becomes necessary to take an efficient approach towards optimum resource allocation so as to make farmers' income productive, thus keeping afloat the farm-firm business going concern. It is in the light of the above that the research on efficient allocation of farm inputs and the effect of agricultural policy on small-scale groundnut production in Niger State of Nigeria was conceptualized. The specific objectives were:

i. To determine the resource-use efficiency among the producers, and,

ii. To examine the effects of agricultural policy on groundnut production in the studied area.

Table 1. Production Trend of Groundnut in Nigeria

Year	Production	Area	Yield	PG (%)	AG (%)	YG (%)
1980	471000	563000	8366	-7.64331	10.47957	-20.2486
1981	530000	650000	8154	11.13208	13.38462	-2.59995
1982	458000	497000	9215	-15.7205	-30.7847	11.51384
1983	591000	650000	9092	22.50423	23.53846	-1.35284
1984	546000	600000	9100	-8.24176	-8.33333	0.087912
1985	621000	594000	10455	12.07729	-1.0101	12.96031
1986	896000	793000	11299	30.69196	25.09458	7.469688
1987	687000	597000	11508	-30.4221	-32.8308	1.816128
1988	1016000	707000	14371	32.38189	15.5587	19.92207
1989	1017000	800000	12713	0.098328	11.625	-13.0418
1990	1166000	707000	16492	12.77873	-13.1542	22.91414
1991	1361000	1127000	12076	14.3277	37.26708	-36.5684
1992	1297000	1046000	12400	-4.93446	-7.74379	2.612903
1993	1323000	1121000	11802	1.965231	6.690455	-5.06694
1994	1453000	1571000	9249	8.947006	28.64418	-27.603
1995	1579000	1767000	8936	7.979734	11.09225	-3.50269
1996	2278000	2266000	10053	30.68481	22.02118	11.11111
1997	2531000	2251500	11241	9.996049	-0.64402	10.56845
1998	2534000	2604700	9729	0.11839	13.5601	-15.5412

Year	Production	Area	Yield	PG (%)	AG (%)	YG (%)
1999	2894000	1929000	15003	12.43953	-35.0285	35.15297
2000	2901000	1934000	15000	0.241296	0.258532	-0.02
2001	2683000	1731000	15500	-8.12523	-11.7273	3.225806
2002	2855000	1878000	15202	6.024518	7.827476	-1.96027
2003	3037000	1985000	15300	5.992756	5.390428	0.640523
2004	3250000	2097000	15498	6.553846	5.340963	1.277584
2005	3478000	2187000	15903	6.555492	4.115226	2.546689
2006	3825000	2224000	17199	9.071895	1.663669	7.535322
2007	2847373	2202638	12927	-34.3343	-0.96984	-33.0471
2008	2872740	2336400	12296	0.883025	5.725133	-5.13175
2009	2977620	2643330	11265	3.522276	11.61149	-9.15224
2010	3799240	2789180	13621	21.6259	5.229135	17.29682
2011	2962627	2353680	12587	-28.2389	-18.5029	-8.21482
2012	3313500	2659800	12458	10.5892	11.50914	-1.03548
2013	2474530	2732700	9055	-33.9042	2.667691	-37.5814
2014	3399158	2799773	12141	27.20168	2.395659	25.41801
2015	3467446	2801756	12376	1.969403	0.070777	1.898836
2016	3581800	2680000	13365	3.192641	-4.54313	7.399925
2017	2420000	2820000	8582	-48.0083	4.964539	-55.7329

Source: FAO, 2020

Note: P, A, Y and G means Production, Area, Yield and Growth rate in percentage.

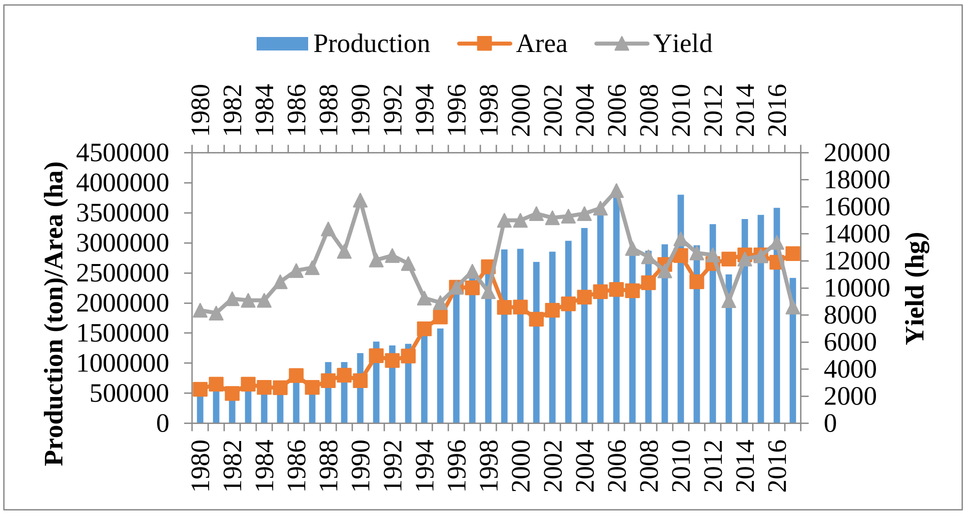

Fig. 1: Production trend of groundnut (1980-2017).

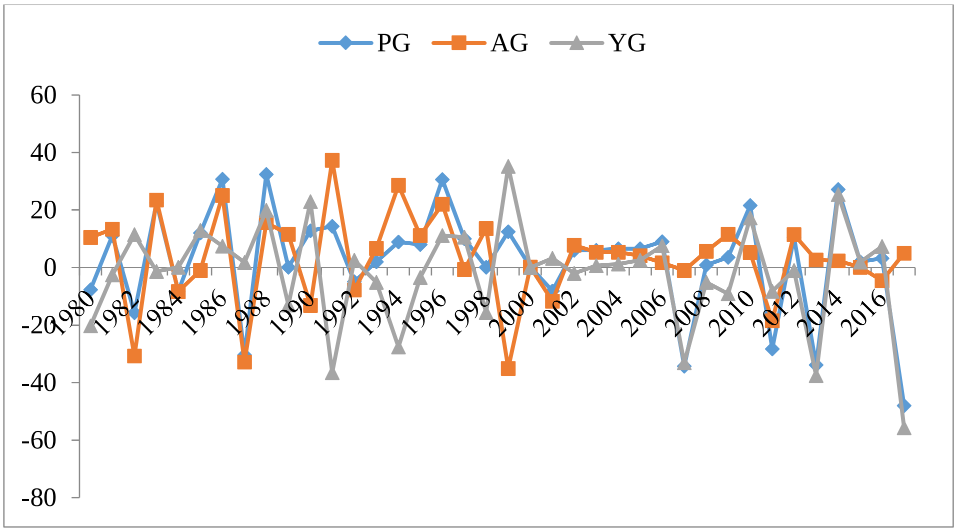

Fig. 2: Annual growth rates of production, area and yield (1980-2017).

Research Methodology

Study Area: The state is located between latitudes 8˚21ˈN – 11˚30N and longitude 3˚30ˈE – 7˚20E of the Greenwich meridian time and is characterized by Guinea savannah vegetation. Most of the inhabitants engaged in agricultural activities *viz.* arable crop production, livestock rearing, hunter, lumbering etc (Sadiq, 2014).

Sampling Techniques and Sample Size: The research adopted a multi-stage sampling technique in which one agricultural zone *viz.* Kuta was conveniently chosen among the three (3) existing zones. Thereafter, two Local Government Areas (LGAs) *viz.* Chanchaga and Shiroro were purposively chosen owing to the preponderance of groundnut producers and the potentials of the LGAs in the cultivation of the crop. Afterward, from each of the chosen LGAs three (3) villages were randomly selected; and from the chosen villages, twenty (20) producers were randomly selected, thus given a total of 120 respondents for the study. Data were elicited through a structured questionnaire complemented with the interview schedule. The first and second objectives were achieved using OLS estimation applied to the multiple regression model and policy analysis matrix (PAM).

Model Specification

1. Multiple regression model

The implicit form is as follow:

$\mathrm{Y} = \mathrm{f}(X_1, X_2, X_3, X_4, X_5)$ .... (1)

While the explicit form is:

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \varepsilon_t$...... (2)

Where:

Y = Output (kg); X_1= Farm size (ha); X_2= Seeds (kg); X_3= NPK (kg); X_4= Manure (kg); X_5 = Herbicides (ltr); X_6 = Human labour (manday); X_7 = Depreciation on capital items;β_0 = Intercept;β_{1-7} = Regression coefficients; and, ε_t = white noise

The functional forms fitted into the specified equation are as follows:

(a) Linear function

$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \dots\dots\dots\dots\dots + \beta_n X_n + \varepsilon_t$ .... (3)

MPP= β

Elasticity = $\beta * \overline{X}/\overline{Y}$

(b) Semi–log function

$Y = \beta_0 + \beta_1 logX_1 + \beta_2 logX_2 + \beta_3 logX_3 \dots\dots\dots\dots + \beta_n logX_n + \varepsilon_t$ ...... (4)

MPP = $\beta/\overline{X}$

Elasticity = $\beta/\overline{Y}$

(c) The Cobb Douglas (double log) function

$logY = \beta_0 + \beta_1 logX_1 + \beta_2 logX_2 + \beta_3 logX_3 \dots\dots\dots + \beta_n logX_n + \varepsilon_t$ .... (5)

MPP = $\beta * \overline{Y}/\overline{X}$

Elasticity = β

(d) Exponential function

$logY = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \dots\dots\dots\dots + \beta_n X_n + \varepsilon_t$.......................... (6)

MPP = $\beta * \overline{Y}$

Elasticity = $\beta * \overline{X}$

Determining technical efficiency of resource use

The elasticity of production was used to estimate the rate of return to scale which is a measure of a firm's success in producing maximum output from a set of variable inputs.

EP = MPP/APP………………………………………………………….. (7)

Where:

EP = elasticity of production

MPP = marginal physical product

APP = average physical product

If

EP =1: constant return to scale

EP < 1: decreasing return to scale

EP > 1: increasing return to scale

Determining the allocative efficiency of resource-use

The following ratio was used to estimate the relative efficiency of resource use (r)

$AEI = MVP/MFC$.. (8)

Where:

MFC or P_x = unit cost of a particular resource

MVP = value added to groundnut output due to the use of an additional unit of input, calculated by multiplying the MPP by the unit price of output i.e. $MPP_{xi} * P_y$

Rule of Thumb

If r = 1, resource is efficiently utilized

If r > 1, resource is underutilized

If r < 1, resource is over-utilized

Economic optimum takes place where *MVP = MFC*. If *AEI* is not equal to *1*, it suggests that resources are not efficiently utilized. Adjustments could, therefore, be made in the quantity of inputs used and costs in the production process to restore *r = 1* and the model is given as follows:

Divergence percentage (D %) $= (1 - 1/r_i) \times 100$ *or* $[\frac{(r_i - 1)}{r_i}] \times 100$....... (9)

2. ***Policy Analysis Matrix (PAM):***

PAM is usually built using farm budget, including revenues and costs, which occur in the form of tradable inputs (production inputs) and domestic resources (land and labor) (Table 2). In PAM, both revenues and costs are evaluated financially (at market prices) and economically (at border prices) to assess the effect/impact of the implemented policy by measuring Nominal Protection Coefficient for outputs and inputs, Effective Protection Coefficient and Comparative Advantage Coefficient (Domestic Resource Cost Coefficient-DRC).

Table 2. PAM structure

Items	Revenue	TIC	Domestic Cost			TDC	NI	VA
			LC	RV	D			
Financial Prices	A	B	C	D	E	F	G	H
Economic Prices	I	J	K	L	M	N	O	P
Policy Effect	Q	R	S	T	U	V	W	X

Note: TIC = Tradable input cost; LC = Labour cost; RV = Rental value; D = Depreciation on capital items; TDC = total domestic cost; NI = Net income; and VA = Value added

Nominal Protection Coefficient for outputs (NPC$_O$): Is the ratio between domestic and economic prices of outputs. It represents such kinds of protection or taxes that prevent equating domestic prices with border prices. It reflects the level of incentives or non-incentives offered to domestic farmers. It is shown below:

$$NPC_O = \frac{A}{I} \quad \text{……………………………………………………………… (10)}$$

NPC> 1 means that domestic prices are higher than border prices, indicating implicit subsidy for producers.

NPC <1 means that domestic prices are lower than border prices, indicating that producers incur implicit taxes.

NPC = 1 means the absence of intervention in price policy, as well as absence of protection.

Nominal Protection Coefficient for inputs (NPC$_I$)**:** It is the ratio between domestic and economic prices of outputs and it is given below:

$$NPC_I = \frac{B}{J} \quad \text{……………………………………………………………….. (11)}$$

NPCI> 1 means that the government subsidizes production inputs.

NPCI <1 means that the government imposes taxes on inputs.

NPCI = 1 means the absence of distortions in input prices.

Effective Protection Coefficient (EPC): It is the ratio of the value-added of a particular product in domestic market price to the value-added in economic price. It measures the net effect/impact of economic policy on domestic output and input markets and it is shown below:

$$EPC = \frac{G}{O} \quad \text{………………………………………………………………….. (12)}$$

EPC = 1 means the absence of distortions.

EPC> 1 means effective protection or incentives for producers.

EPC <1 means negative protection in the form of taxes imposed on producers.

The nominal protection coefficient for both inputs and outputs is used to estimate the structure of incentives at the commodity level, while the effective protection coefficient is a measure of price incentives.

Domestic Resource Cost Coefficient (DRC): It is the ratio between costs and benefits and it measures the efficiency or comparative advantage of a commodity in a system. It is given below:

$$\boldsymbol{DRC = \frac{N}{P}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (13)$$

DRC <1 means that using less than one unit of domestic resources yields one unit of hard currency, an indication that the country enjoys a comparative advantage.

DRC> 1 means that more than one unit of domestic resources is used to acquire one unit of hard currency, an indication that the country has no comparative advantage in the global market. If the opportunity cost of using domestic resources exceeds the value-added estimated at world prices, it means that the economic activity is unprofitable.

Following World Bank (2000), the economic value for production factors is as follows: seeds are 1.12; inorganic fertilizersare1.45; Biocides are1.09; human labour is 0.75; Machinery is 1.12; economic rent i.e. opportunity cost for farm size; while for any other factors their current nominal value is taken.

Results and Discussion

Production Estimates and Inputs Allocation Efficiency

The results of the ordinary least square (OLS) estimation showed the exponential functional form to be the best fit for the specified multiple regression model among all the tried functional forms as it satisfied the economic, statistical and econometric criteria (Table 3). Thus, it was chosen as the lead equation to give an exploratory insight on groundnut production. The diagnostic test results showed the residual to be homoscedastic and normally distributed as evident by the Bruesch-Pagan and Chi^2 test statistics respectively, which were not different from zero at 10% degree of freedom. In addition, it was observed that the explanatory variables did not exhibit collinear relationship and the model specification is adequate as indicated by their respective variance inflation factors (VIF) which are less than 10.0 and the non-significant of the test statistic at 10% probability level, respectively.

Furthermore, the result showed the coefficient of multiple determination (R^2) to be 0.8904, implying that 89.04% of the variation in the output of the groundnut was influenced by the stimulus variables included in the model while the joint influence of the disturbed economic reality accounts for 10.96%. The predictor variables found to have an influence on the groundnut output were seed, fertilizer, herbicides, farm size and depreciation on capital items as evident by their respective statistical properties which were different from zero at 10% degree of freedom. The positive significance of the seed coefficient implied that the farmers used improved varieties and adopted the recommended practices, thus exerting a positive effect on the output of the groundnut. Therefore, the marginal and elasticity implications of a unit increase in the use of improved seed varieties by 1kg would increase the groundnut output level by 75.65kg and 0.508% respectively. A similar finding was reported by Zekeri *et al*.(2013), Audu *et al*.(2017) and Thulasiram *et al*.(2018).The positive significant of the depreciation on the capital items coefficient indicated high intensity in the use of primitive implements in the cultivation of this crop on a small-scale basis. Thus, the marginal and elasticity implications of a unit increase in the rate of depreciation of capital items by 1 naira will make the farmers to increase their groundnut output level by 0.024kg and 0.074% respectively.

The positive significant and inelastic of the farm size coefficient showed the presence of marginal effect of economies of size which is expected, given that the crop is cultivated on a small-scale basis. This did not come as a surprise as smallholder farmers lack economic capital but rather possessed social capital, thus farm outputs are mostly in small quantity. Therefore, the marginal and elasticity implications of a unit increase in the farm size by 1 hectare would increase output by 222.78kg and 0.328% respectively. This conforms with the findings of Bathon *et al*. (2016) and Audu *et al*. (2017). The positive significant of the herbicides coefficient signified the appropriate dosage application of the agrochemical, thus exerting a positive influence on the output level of groundnut in the studied area. Thus, the marginal and elasticity implications of a unit increase in the use of herbicides by 1 litre would increase output level by 115.95kg and 0.091% respectively. This agrees with the findings of Bathon *et al*. (2016) and Thulasiram *et al*. (2018) who in their various research reported a direct relation between biocides and groundnut output level. The negative significance of the fertilizer coefficient revealed an over-dosage in the application of the agro-chemical. Therefore, the marginal and elasticity implications of a unit increase in the quantity of inorganic fertilizer by 1 kg would decrease the output level of groundnut by 2.23kg and 0.186% respectively. Audu *et al*. (2017) found a contrary finding in their study.

The positive non-significant of the organic manure coefficient indicates insufficient use of this form of fertilizer owing to the use of close substitute i.e. the inorganic fertilizer in the studied area. In addition, this form of fertilizer is not in abundance in the studied area and the farmers' quest for high yield affected the use of organic residue fertilizer in the studied area. The positive non-significant of the human labour coefficient showed the substitution effect of herbicides, thus reducing the use of human labour for manual operation in the production of this crop in the studied area. The use of weed suppressant has become a common practice among the farmers in the studied area despite its consequence on the environmental condition of the soil and the climate. The positive significant of the managerial efficiency parameter indicated that the prevailing technology at the disposal of the farmers contributed to the output level of the groundnut production in the studied area.

The result of the return to scale showed the farmers to be operating in an uneconomic production stage i.e. increasing return to scale as indicated by the index value which is greater than unity (1.032). This implies that the farmers have the chance to increase the scope of their production to attain an economically viable point i.e. optimum production point which lies within the economic region of production by increasing the use of the resource at their disposal judiciously keeping in view the prevailing technology and market prices of input-output in the studied area (Table 3).

A perusal of Table 4 showed the highest contribution to the output owing to additional input to come from farm size while depreciation on capital items accounted for the least contribution to the output level as indicated by their respective marginal physical product (MPP) value. However, inorganic fertilizer contribution to the output level was negative due to inappropriate application owing to the benefits of subsidy and a bulk discount rate as farmers constituted themselves into farmers' groups in the studied area.

Furthermore, the empirical evidence showed that the farmers were not efficient in the allocation of all the farm inputs as evident by the under-utilization of almost all the resources except inorganic fertilizer and labour that were over-utilized (Table 4). Over-utilization of the inorganic fertilizer owes to the provision of subsidy coupled with bulk discount in the purchase of the input as most of the farmer groups have direct link to the agro-input suppliers. Thus, the farmers are advised to adjust their inputs if they want to take advantage of profit optimization in groundnut production in the studied area.

Effect of Agricultural Policy on Groundnut Production

The PAM results showed that the per hectare revenue of the financial and economic prices reached₦53670.39 and ₦71560.52 respectively, thus making the government agricultural policy on the producers to be ₦17890.13 (Table 5). Thus, this indicates that the farmers incurred an implicit tax of ₦17890.13 per hectare during the period of study. Furthermore, the agricultural policy has an effect on groundnut production as the cost of cultivation declined by ₦1841.13 during the production season. For the net income which reflects the implicit taxes and subsidy received, evidence showed the financial and economic prices to be ₦27425.23 and ₦44046.27 respectively, thereby resulting in policy effect of ₦16621.03. Therefore, it can be suggested that the farmers incurred implicit taxes to the tune of ₦16621.03 per hectare.

Table 3. Production determinants of groundnut output

Inputs	Ordinary least square (OLS)				Col. Test
	Linear	Exponential (+)	Semi-log	Double log	VIF (+)
Constant	105.376(197.88) [0.532]^{NS}	6.0904(0.1527) [39.86]***	1860.50(2084.12) [0.892]^{NS}	5.6571(0.9727) [5.815]***	
Farm size	317.271(75.948) [4.177]***	0.1698(0.0586) [2.897]***	822.777(176.057) [4.673]***	0.4908(0.0821) [5.974]***	2.442
Seeds	54.959(15.228) [3.609]***	0.05767(0.0118) [4.905]***	351.96(168.36) [2.090]**	0.3565(0.07858) [4.536]***	1.988
NPK	0.0634(1.0342) [0.0613]^{NS}	−0.001699(0.000798) [2.128]**	171.29(94.227) [1.818]*	0.02567(0.04398) [0.583]^{NS}	9.714
Manure	−0.00423(0.1627) [0.026]^{NS}	0.00013(0.000126) [1.052]^{NS}	−366.94(275.12) [1.334]^{NS}	−0.00602(0.1284) [0.0469]^{NS}	1.032
Herbicides	31.7271(7.594) [4.118]***	0.0884 (0.021) [4.2095]***	186.05(208.41) [0.893]^{NS}	0.5657(0.9727) [0.5815]^{NS}	
Human labour	1.6565(4.5609) [0.3632]^{NS}	0.00417(0.00352) [1.185]^{NS}	26.1758(110.746) [0.236]^{NS}	0.00992(0.05169) [0.192]^{NS}	1.153
Depreciation on capital items	0.01831(0.0108) [1.683]*	1.827e-5(8.398e-6) [2.175]**	5.6876(41.911) [0.135]^{NS}	0.0407(0.0195) [2.083]**	1.077
$\sum \beta$		1.031684			
R^2	0.923	0.8904	0.8945	0.9451	
Adjusted R^2	0.919	0.8845	0.8889	0.9422	
F-stat	225.65***	153.01***	159.76	324.61****	
Heteroskedasticity (B-G)	164.56{6.3e-33}***	0.388{0.767}^{NS}	46.306{6.14e-6}***	43.281{1.03e-7}***	
Normality test	48.00{3.76e-11}***	0.5265{0.718}^{NS}	15.260{0.00048}***	9.062{0.0107}**	
RESET Test	13.381{3.88e-4}***	0.6537{0.1736}^{NS}	59.569{5.33e-12}***	1.5e-4{0.9902}^{NS}	

Source: Field survey, 2018

Note: * ** *** ^{NS} significance at 1%, 5%, 10% and Non-significant respectively.

Values in ( ); [ ]; and { } are standard error, t-statistic and probability value, while Col. = Collinearity

Table 4. Technical and Allocative efficiencies of groundnut farmers

Inputs	Mean	APP	EP	MPP	MPV	MFC	AEI	D(%)	Decision
Farm size	1.9333	678.4772	0.328357	222.7831	16708.73	5000	3.341746	70.07552	UU
Seed	8.8	149.0568	0.507505	75.64705	5673.529	320	17.72978	94.35977	UU
NPK	109.17	12.01521	-0.18553	-2.22923	-167.193	56	-2.98558	133.4943	OU
Manure	1013.3	1.294483	0.133857	0.173276	12.99567	5	2.599134	61.52564	UU
Herbicides	1.0323	1270.658	0.091255	115.9543	8696.571	1000	8.696571	88.50122	UU
Human labour	19.776	66.32787	0.082545	5.475036	410.6277	750	0.547504	-82.6472	OU
Dep. on cap.	4034.4	0.325129	0.073699	0.023962	1.797131	1.18	1.522992	34.33978	UU

Source: Field survey, 2016

Note: UU = Under-utilization; OU = Over-utilization

RTS = 1.032; Output $\overline{Y}$ = 1311.70; P_y/kg = ₦75

Table 5. Effect of Agricultural Policy on Groundnut Production

Items	Revenue	Tradable Input Cost	Domestic Cost			TDC	Net Income	Value Added
			Labour cost	Rental Value	Depreciation			
Financial Prices	53670.39	9583.821	10288.47	3000	3372.86	16661.33	27425.23	44086.57
Economic Prices	71560.52	11425.03	7716.353	5000	3372.86	16089.21	44046.27	60135.48
Policy Effect	-17890.13	-1841.213	2572.12	2000	0	572.118	-16621.03	-16048.92

The NPC_O value revealed the absence of fair production policy as evident by its coefficient (0.75) which is less than unity. This indicates that the domestic price of groundnut produced by the farmers is lower than the international prices, thus resulting in the farmers incurring implicit taxes amounting to 25% as they received only 75% of the real price from their output. This vividly showed that the current agricultural policy is not in favour of the farmers during the study period. The NPC_I index indicates that the farmers received a subsidy of 16.12% on the production inputs as evident by the index which is lower than unity. This implies that input subsidy to the farmers is declining, an indication of economic compliance with the implementation of government agricultural policy on gradual removal of subsidy on agro-inputs until it attained price level proportionate to their market value. Thus, it can be inferred that the deregulation policy resulted in a limited subsidy on the production inputs in the studied area.

The EPC index (0.733) been lower than unity, indicates the absence of protection policy and the government has been imposing taxes either directly or indirectly, or it has been relaxing tariff on groundnut importation. Also, the DRC index (0.268) been less than unity showed that the studied area had a comparative advantage in the production of groundnut. In addition, it means that domestic production of groundnut is preferred to reliance on groundnut importation.

Conclusion and recommendations

Based on the findings it can be inferred that the production of groundnut in the studied area has been affected by the excess application of inorganic fertilizer. In addition, the farmers were not economically rational in the use of their inputs which is the basis of profit optimization in the studied area. Furthermore, the empirical evidence showed the current agricultural policy is not to be in the favour of the farmers in the studied area coupled with the absence of protectionist policy despite the deregulation policy which limited subsidy supply. Therefore, the change agents should re-train the farmers on the recommended dosage of agro-chemical application, especially inorganic fertilizer. In addition, the government should improvise protectionist policy so that the groundnut producers in the studied area can compete favourable in a liberal competitive groundnut market both locally and internationally.

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FACTORS AFFECTING VEGETABLE MARKETING CHANNEL IN RANGAMATI HILL DISTRICT OF BANGLADESH

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Abstract

50 respondents were chosen randomly for primary data collection. In this study, principal component method was applied to estimate the factor loadings and communalities. 'Varimax' factor rotation was used to estimate factor loadings. The Kaiser-Meyer-Olkin (KMO) and Bartlett's Test were also applied. Besides, to identify the factors coefficient value and significance level multiple logistic regression model was applied. The study identified two major vegetable marketing channels, viz. Farmer- Local Market- Consumer and Farmer- Local Market- Local Retailer- Consumer; and three value addition activities, viz. washing, grading and bundling of vegetables. Problems associated with marketing channels were identified as lack of proper irrigation system, better transportation, diversified market, market infrastructure, storage facility, knowledge about new technology and marketing skill, proper guidance and training. The study recognized four factors that affect vegetable marketing channels. These are: Marketing factor (Factor 1), Economic factor (Factor 2), Social factor (Factor 3) and External factor (Factor 4). The study recommended that policy makers should come forward to ensure dissemination of appropriate technologies, adequate training for indigenous farmers, better transportation system, well established market infrastructure and integrate all activities of participants like farmers, local retailers, government, NGOs etc. to ensure a smooth, fair and profitable vegetable marketing channel.

Keywords: Vegetable marketing, Factor analysis, Marketing channel, Value addition.

Introduction

Agriculture is the key driver of the growth of economy of Bangladesh. Agriculture provides employment to about 41% of its total labor forces (BBS, 2016). The contribution of the vegetable farming sub-sector to GDP is 1.60 percent in 2016-17 (MoA, 2017). Farmers in the hill tract areas produce seasonal vegetables for their family consumption or commercial purpose. In the case of commercial production, farmers face various problems. They do not get proper price of their produce due to the lack of proper marketing chain. Agriculture based industries are also unavailable. The vegetable market conduct is

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characterized by unethical practices of cheating and information collusion that led to uncompetitive market behavior even though the calculated concentration ratio did not indicate oligoposony market behavior (Teka, 2009). Marketing of vegetables is very complex and risky in hilly areas due to bulkiness, seasonality highly perishability and huge fluctuation in prices. Development of an effective marketing system is an important aspect to boost up agriculture development through commercialization and diversification (Girma, 2009). Producing and marketing of vegetables are always a profitable option to enhance farm income and employment opportunity. Surplus supply of vegetables in the growing season reduces the market price and shortage of supply of vegetables in the off season/lean period the price hike causes unusual misery to the consumers.

Due to technological innovation, vegetables are now growing throughout the year across the country. There is a great opportunity to increase vegetable production in hilly areas through development of marketing channels and improving local market as well. In true sense, Bangladesh has fallow land in hilly region which can be brought under cultivation. Indigenous and local farmers traditionally producing vegetables though specific constraints of marketing were not fully identified and quantified. There can be an assessment of these barriers to improve marketing which ultimately will increase vegetable production. Therefore, the study was undertaken with following objectives.

- To depict the existing vegetable marketing channel and value addition activities in Rangamati Hill district;
- To find out the problems and constraints associated with vegetable marketing in the study area;
- To determine the factors that affect vegetable marketing channel in the study region; and
- To make some recommendations to develop the marketing system in the study area.

Materials and methods

Sampling Procedure and Data Collection

The study was carried out in Khandhobchor, Aamchuri, Katachuri, Rangapani and Ashambosti villages at Sadar Upazila of Rangamati district. Keeping in mind the objectives of the study, the areas were selected considering easy accessibility and favorable for vegetable production and marketing. As the population size was not readily available, 50 respondents were selected considering availability at the first sight. Wherever possible, discussions were held with farming households on an informal basis. Primary data were collected during July 2017 to November 2017. A pre-tested interview schedule and direct interview method were used for the collection of data. Focus Group Discussion (FGD) and the Key Informants Interviews (KII) were also done.

Statistical Analysis (Factor Analysis)

Factor analysis is a multivariate statistical technique that addresses itself to the study of interrelationships among a total set of observed variables. The technique allows looking at groups of variables that tend to be correlated to one another and identify underlying dimensions that explain these correlations. While in multiple regression model, one variable is explicitly considered as dependent variable and all the other variables as the predictors; in factor analysis all the variables are considered as dependent variables simultaneously. In a sense, each of the observed variables is considered as a dependent variable that is a function of some underlying, latent, and hypothetical set of factors. Conversely, one can look at each factor as dependent variable that is a function of the observed variables.

If $\{X_1, X_2, ----, X_n\}$ be a set of n observed variables and $\{F_1, F_2, -----, F_m\}$ be a set of unobservable variables then the factor analysis model can be expressed as-

$X_1 - \mu_1 = l_{11}F_1 + l_{12}F_2 + -------- + l_{1m}F_m + \varepsilon_1$

$X_2 - \mu_2 = l_{21}F_1 + l_{22}F_2 + -------- + l_{2m}F_m + \varepsilon_2$

$X_n - \mu_n = l_{n1}F_1 + l_{n2}F_2 + -------- + l_{nm}F_m + \varepsilon_n$

Where, μ_i is the mean of X_i, ε_i is error or specific factor. The coefficient l_{ij} is the loading of i-th variable on the j-th factor. In matrix notation the factor analysis model can be expressed as

$X - \mu = LF + \varepsilon$

Where $L_{n\times m}$ is the matrix of factor loadings.

The study considers principal component method to estimate the factor loadings and communalities [$h_i^2 = \sum_{i=1}^{m} l_{ij}^2$], a measure of the variation of observed variables through factors. 'Varimax', factor rotation is adopted to find estimate of factor loadings. Moreover, multiple logistic regression model was used to identify the factors coefficient value and significance level.

KMO and Bartlett's Test: The Kaiser-Meyer-Olkin measure of sampling adequacy is a statistic that indicates the proportion of variance in variables that might be caused by underlying factors. High values (close to 1.0) generally indicate that a factor analysis may be useful with data. If the value is less than 0.50, the results of the factor analysis probably won't be very useful.

Bartlett's test of sphericity: The test indicates that variables are unrelated and therefore unsuitable for structure detection. Small values (less than 0.05) of the significance level indicate that a factor analysis may be useful with data.

Results and discussion

Marketing Channel and Value Addition

There were two major marketing channels in the study area; those are:

Channel 1: Farmer- Local Market- Consumer (85% farmers followed)

Channel 2: Farmer- Local Market- Local Retailer- Consumer (15% farmers followed)

In channel one, after harvesting their products farmers went to the local markets directly either by boat (manual or engine powered) or by CNG auto rickshaw. Roadside marketing is by far the most common direct marketing system on those local markets. Location is very important for roadside marketing, because these roadside markets are too large. Farmers who came first took the better place beside the main market and more customers went there, bargain and bought their daily needs. If it is too far from the main market like near to the boat ghat/station customers usually do not go there and products remain unsold. So channel one shows the direct marketing.

In channel two, after harvesting their products farmers went to the local markets directly either by boat (manual or engine powered) or by CNG auto rickshaw. Farmers who became late to get better position in the market usually had to sell their products beside the road far from the main stream market near the boat ghat/station which was basically awkward position. Since, customers usually do not go or gather there, products remain unsold. In that situation, farmers sold it to the nearest shop of their position. Those are called local retailers. Those local retailers bought these products from producers and then sold it to their local customers.

Channel-1 was more preferable to both farmers and consumers. Consumers want to purchase from farmers directly to get fresh vegetables with low price and farmers want reasonable price from consumers. Most of the farmers (85%) followed channel-1 and the remaining (15%) farmers followed channel-2.

It was observed that farmers basically get involve in three types of value addition activities when they marketed vegetables (cucumber, brinjal, pumpkin, bean, tomato). Those were washing, grading and bundling. (Table-1) study showed that 24% farmers did washing after picking their products, 36% farmers did both sorting/grading and washing for value addition. 6% farmers did both washing and bundling and 34% farmers did sorting/grading, washing and bundling. From the observation it can be said that all farmers did washing their products to get more value.

Table 1. Value addition activities by indigenous community

Value Addition Activities	No. of Respondent	Percentage
Washing the vegetables after picking	12	24
Washing and Sorting/grading	18	36
Washing and bundling	3	6
Washing, sorting/grading and bundling	17	34
Total	50	100

Source: Field survey

After washing, grading/sorting and bundling the average price variation of the products was Tk. 6.33 per kg greater than the original price. Maximum price variation was Tk. 10.00 per kg greater than the original price and minimum price variation was Tk. 3.00 per kg greater than the original price of the products.

Table 2. Price variation after value addition by indigenous community

Price variation after value addition	Amount in Tk./kg
Average	6.33
Maximum	10.00
Minimum	3.00

Source: Field survey

Problems and Constraints Associated with Vegetable Marketing

Farming as a source of livelihood has been an age-old practice for thousands of local farmers in Rangamati. In the present study, an attempt had been made to identify and analyze the major problems and constraints faced by the farmers in production and marketing of vegetables.

1. **Quality seed:** For better yield good quality of seed is very important. Poor quality seeds often give poor results. Most of the local farmers used local seeds of traditional cultivars. Quality of locally available seeds are hardly maintained. That‘s why they didn‘t get the expected yield. Only 20% farmers used both local and hybrid seeds for cultivation.

Variety	No. of Respondent	Percentage
Local	40	80
Local and hybrid	10	20

Source: Field survey.

2. **Lack of proper irrigation system:** The main source of irrigation is Kaptai Lake in the study area. All the respondents replied that they suffer from lack of water from the Kaptai Lake in the summer. They also suffer from paucity of uninterrupted supply of electricity. They don‘t get required electricity

supply, that‘s why they don‘t use electric motors for supplying water from the lake. As the maximum cultivable lands are hilly, farmers didn‘t arrange proper irrigation management. Lack of knowledge about irrigation system is also present among the respondents.

3. **Transportation system:** Most of the respondents used manual or engine powered boats (82%) and the remaining 18% of the respondents used CNG auto rickshaw for transportation of their products. High fuel price and lack of engine powered boat severely affected the marketing system of the indigenous farmers. The farmers cannot ensure delivery of their products in time. Deterioration and wastage of their products couldn‘t be lessening due to delay transportation.
4. **Input cost:** All the respondents reported that high price of input was one of the most important problem for farming. Cost of fertilizer, seeds, irrigation and land preparation affects significantly the production rate of the indigenous farmers.
5. **Lack of diversified market:** The most common problem with the farmers is marketing of their produce irregularly due to lack of diversified market. More marketing opportunity and diversified market help the farmers to sell their products easily with maximum price. It shows that 66% of the respondents sold their product in one market and the remaining 34% respondents sold in different markets.
6. **Lack of market infrastructure:** All the respondents said that they didn‘t have well organized places or infrastructure facilities like traditional markets. So, they sell their products on road side in the open air directly to the consumers. Moreover, who arrived late in the market had to sell their products at the end of the main market where customers usually don‘t go. That‘s why price variation on those places is higher than the other place of the market.
7. **Lack of storage facility:** The study revealed that 62% of the respondents have no storage facilities. Only 38% farmers seemed that it was not a problem.
8. **Lack of knowledge about new technology and marketing skill:** Many farmers in rural areas do not have up-to-date information on how to grow food efficiently and economically. In the study, it was found that 80% of the local farmers followed traditional farming. They didn‘t have idea about modern farming technology and marketing skills.
9. **Lack of proper guidance and training:** Seventy two percent of the respondents received training but they mentioned that those were not up to date, and they didn‘t improvise it. It was found that 58% of the respondents had no involvement with NGOs’, and 50% of the respondents didn‘t get any kind of assistance and guidance from the Government agencies.

Table 3. Problems and Constraints Associated with Vegetable Marketing

SI No	Problems and Constraints	Response criteria	Percentage
1	Quality seeds	Local	80
		Local and hybrid	20
2	Lack of proper irrigation system	Yes	100
		No	0
3	Transportation system	Manual or engine powered boats	82
		CNG auto rickshaw	18
4	High input cost	Yes	100
		No	0
5	Lack of diversified market	Yes	66
		No	34
6	Lack of market infrastructure	Yes	100
		No	0
7	Lack of storage facility	Yes	62
		No	38
8	Lack of knowledge about new technology and marketing skill	Yes	80
		No	20
9	Lack of proper guidance and training	Received training but not up-to-date	72
		Involvement with NGOs’	42
		Receive assistance and guidance from the govt. agencies	50

Source: Field survey.

Factors Analysis

With KMO and Bartlett's Test, the KMO value was 0.821, indicates factor analysis was useful with the data and Bartlett's test of sphericity shows a significance level of 1% which indicates that factor analysis was also useful with the data. The study identified four key factors based on the maximum variation of the factors that affect vegetable marketing channel in the study area. These factors are classified into four groups. These are Marketing (F_1), Economic (F_2), Social (F_3) and External (F_4) factors (Table 4).

Table 4. Factors analysis affecting vegetable marketing channel

Causes that affect vegetable marketing channel	Factor loading	Communalities
F_1= Marketing factor		
No. of farmers	0.778	0.856
Mode of transport	0.732	0.821
Market structure	0.726	0.731
Storage facility	0.707	0.842
Selected place for marketing	0.724	0.921
Location	0.542	0.726
Value addition	0.429	0.868
Price variation	-0.585	0.834
Variety	0.453	0.721
F_2= Economic factor		
Yield	0.660	0.846
Total expense	-0.584	0.720
Total income	0.621	0.879
F_3= Social factor		
Age	-0.465	0.653
Education	-0.557	0.641
Family size	0.692	0.746
Place of production	-0.542	0.743
Land size	0.452	
Health status	0.653	
F_4= External factor		
Training	-0.218	0.781
NGO involvement	0.314	0.819
Assistance from govt. agencies	0.631	0.846
Eigen value: F1= 6.454, F2= 3.476, F3= 4.680, F4= 6.843		
Percent of variation: F1= 18.429, F2= 14.945, F3= 13.243, F4= 12.268		
Cumulative percent of variation: F1= 23.419, F2= 32.395, F3= 45.495, F4= 45.756		
KMO= 0.821 and only factor loading ≥58 has been shown in the table, P-value=0.00		

Extraction method: Principle Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Above factors' elements were arranged according to their respective importance of factor loadings. Negative value of price variation in Factor 1; total expense in Factor 2; age, education and place of production in Factor 3; and training in Factor 4 indicated that these were inversely related to Factor 1, Factor 2, Factor 3 and Factor 4 respectively.

The result suggested that these four factors were mainly responsible for affecting vegetable marketing channel in the study area. Therefore, to identify these factors coefficient value and significance level, here multiple logistic regression model was done. In this model, factors were terms as variable. This model was also helpful to find out the relation between dependent variable and independent variable. Here, dependent variable was the quantity of vegetables supplied by growers and independent variables were education, age, family size, market price, high input price, labor wages, variety, location of market, market structure, marketing policy, supply and number of growers etc.

Conclusion

There were only two vegetable marketing channels prevailed in the study areas. Local farmers are relatively inefficient due to lack of proper irrigation system, Lack of quick transportation, high transportation cost, lacking diversified market and market infrastructure, low storage facility, access to new technology, training and marketing skill. There is an opportunity of improvement of marketing channel through technological infrastructure and extension of the innovated technology.

Recommendations

Following specific recommendations are made based on the findings of the study.

- Well established market infrastructure is inevitable to ensure fair price for the farmers.
- Most of the farmers and consumers prefer direct marketing. So, Capacity building and efficiency improvement of the farmers can have a great impact to direct marketing.
- New initiative for value addition activities is required to enhance functions of the marketing channel to promote differentiated products.
- Dissemination of appropriate technologies, stabilizing the market and prices, inputs with reasonable price to increase the vegetable production and performance of marketing channel.
- Providing better transportation system for quick delivery and storage facilities will encourage the farming communities

- Adequate training should be provided to the farmers with improve technologies.
- Credit facilities should be enhanced from both private and government institutions on nominal terms and conditions.

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DETERMINATION OF OPTIMUM RATE OF NITROGEN, PHOSPHORUS, POTASSIUM AND BORON FOR LEAF AND SEED YIELD OF LETTUCE

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Abstract

The experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, during October 2012 to May 2013 to determine the optimum rate of nutrients for sustainable lettuce production. Nineteen treatment combinations were considered with five levels of each elements such as nitrogen viz. 0, 50, 100, 150 and 200 kg ha^{-1}; phosphorus viz. 0, 25, 50, 75 and 100 kg ha^{-1}; potassium viz. 0, 50, 100, 150 and 200 kg ha^{-1}; boron viz. 0, 0.5, 1.0, 1.5 and 2.0 kg ha^{-1}. Results revealed that treatment T_3 ($N_{100}P_{50}K_{100}B_{1.0}$) showed the maximum leaf and seed yield of lettuce. Fertilizer doses under T_3 also showed the highest gross margin Tk. 305825 and Tk. 2816675 ha^{-1} and BCR 7.50 and 70.0 for leaf and seed yield, respectively. But, from regression analysis optimum doses of nitrogen, phosphorus, potassium and boron for maximum leaf yield (23.11 ton ha^{-1}) and seed yield (571.5 kg ha^{-1}) were $N_{143}P_{74}K_{95}B_{1.26}$ and $N_{136.4}P_{67.8}K_{118.0}B_{1.0}$, respectively that could be recommended as the best combination of nutrients for achieving higher leaf and seed yield of lettuce.

Keywords: Lettuce, fertilizer, yield, seed production, BCR.

Introduction

Lettuce (*Lactuca sativa* L.) is the most popular and important nutritious leafy salad vegetable. Lettuce is produced commercially in many countries worldwide and is also widely grown as a vegetable in home gardens (Rubatzky and Yamaguchi, 1997). Optimal fertilizer management and efficient use of N, P, K and boron (B) are necessary for improve yield and quality, and to reduce production cost of lettuce (Hoque *et al*., 2010).

Nitrogen is an essential and important determinant plant nutrient for growth and development of crop plants (Tanaka *et al*., 1984). It is the most important fertilizer nutrient for lettuce production which exhibits marked effect on the vegetative growth, leaf and seed yield, fibre and protein content of lettuce.

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Phosphorus plays a vital role in cell division, seed formation, crop maturation and also improves the quality of seed. Potassium increases water holding capacity of plant tissue, succulence of vegetables and retains good condition for longer period (Ahammed, 2009). Boron (B) is an element for the growth of new cells. Boron deficiency in soil causes reduction in number and retention of flowers, pollen germination and pollen tube growth are reduced resulting sterility in seeds (Katyal and Randhawa, 1983).

As a new crop, farmers face various problems since detailed fertilizer package of lettuce is not available. Judicious application of fertilizer has great impact on growth and yield of crop plants. Research information regarding the suitable dose of NPK and B for the satisfactory production of lettuce is meager in Bangladesh. The present investigation was therefore, undertaken with a view to determining the suitable dose of N, P, K and B in order to maximize the leaf and seed yield of lettuce in Salna soils of Bangladesh.

Materials and Methods

The experimental site and soil characters

The experiment was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, during the period from October 2012 to May 2013. The experimental site located in the centre of the agro-ecological zone of Madhupur Tract (AEZ-28). The experimental plot was high land having silty clay loam soil. The soil was slightly acidic (pH-6.5) and low in organic matter and total-N (Table 1).

Table 1. Results of the chemical analysis of initial soil sample of the experimental plot

Soil properties	Analytical value		Optimum value
	2011-12	2012-13	
Soil pH	6.50	6.60	-
Organic matter (%)	0.95	0.95	-
Total N (%)	0.030	0.30	3.00
Available P (µg/ml)	45.00	43.00	-
Exchangeable K (meq/100ml)	0.36	0.35	1.50
B (ppm)	1.50	1.50	-
Ca (meq/100ml)	15.00	15.00	18.00
Mg (meq/100ml)	5.0	5.0	9.00
S (ppm)	15.00	14.00	60.00

Experimental design and treatment details

The experiment was laid out in a randomized complete block design (RCBD) with three replications. There were nineteen treatments containing five levels of each elements such as nitrogen viz. 0, 50, 100, 150 and 200 kg ha^{-1}; phosphorus viz. 0, 25, 50, 75 and 100 kg ha^{-1}; potassium viz. 0, 50, 100, 150 and 200 kg ha^{-1}; boron viz. 0, 0.5, 1.0, 1.5 and 2.0 kg ha^{-1}. Nineteen treatment combinations (including one control and one cow dung treatment) were selected with those levels of N, P, K and B according to the North Carolina University, USA design which were as follows:

Treatment No.	Treatment dose ($kgha^{-1}$)			
	N	P	K	B
T_1	0	50	100	1.0
T_2	50	50	100	1.0
T_3	100	50	100	1.0
T_4	150	50	100	1.0
T_5	200	50	100	1.0
T_6	100	0	100	1.0
T_7	100	25	100	1.0
T_8	100	75	100	1.0
T_9	100	100	100	1.0
T_{10}	100	50	0	1.0
T_{11}	100	50	50	1.0
T_{12}	100	50	150	1.0
T_{13}	100	50	200	1.0
T_{14}	100	50	100	0
T_{15}	100	50	100	0.5
T_{16}	100	50	100	1.5
T_{17}	100	50	100	2.0
T_{18} (Control)	0	0	0	0
T_{19}	Only Cow dung @ 10 ton/ha			

Planting/sowing

Lettuce genotype LS_{003} was used as planting material, which was a selected line for its outstanding performance. Thirty days old seedlings were transplanted on 26th November 2012, two days after final land preparation.

Fertilizer application

Cow dung was mixed up with the soil during final land preparation. The entire quantity of TSP, MoP and boric acid were applied during land preparation. Urea was applied in three equal splits at 7, 17 and 30 days after transplanting (DAT) followed by irrigation.

Intercultural operations

Irrigation was given at an interval of 8-10 days depending on the soil moisture content. Two weedings were done at 10 and 20 DAT.

Data collection

For leaf yield, 50% plants i.e. 12 plants from each plot were uprooted at 40 DAT. Out of them 5 plants were randomly selected for different data collection. Remaining 12 plants were well managed for further growth to record the seed yield data. In each unit plot 5 plants were selected randomly for recording data on different yield contributing characters for seed yield. Lettuce seed was harvested from 22 - 24 March in 2013.

Calculation of optimum dose

To determine optimum fertilizer dose for maximum yield, polynomial regression analysis was done for its calculation. The following equation used to calculate the optimum dose (Ahammed, 2009 and Paul, 2009):

$Y = -ax+bx+c$

Here, Y= yield (t ha^{-1})

x= the dose of nutrient (kg ha^{-1})

$Y (max) = -b/2a$.

The maximum yield is obtained when the marginal production (MP) is zero. MP is calculated by differentiating the first x derivative of y.

$MP=dy/dx=b+2ax$

$0= b+2ax$

$x=-b/2a$

Economic evaluation of different fertilizer combination was done by showing the benefit cost ratio (BCR). Gross return and variable costs were calculated considering the present market price of the materials (Islam *et al.* 2007).

Statistical analysis

The analysis of variance for various parameters was performed following ANOVA (analysis of variance) technique. When F was significant at the $P \leq 0.05$ level, treatment means were separated using DMRT. Data were analyzed following standard procedure using MSTAT-C program.

Results and discussion

The results obtained from this experiment have been presented and discussed character wise under separate headings in this chapter. The effect of N, P, K and

B on lettuce leaf and seed production have been shown in Tables 2 to 9 and Figures 1 to 10.

1. Growth, Leaf yield and yield contributing characters of lettuce

Plant height

Different levels of N, P, K and B had significant influence on plant height of lettuce at 40 days after transplanting (Table 2.). Plant height increased gradually with increase in N, P, K and B levels up to the recommended dose (T_3). The maximum plant height (23.27 cm) was recorded in T_4 ($N_{150}P_{50}K_{100}B_{1.0}$) which was statistically identical to T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$), T_3 ($N_{100}P_{50}K_{100}B_{1.0}$), T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$), T_5 ($N_{200}P_{50}K_{100}B_{1.0}$) and T_{15} ($N_{100}P_{50}K_{100}B_{0.50}$). The minimum plant height (13.20 cm) was recorded in the control (T_{18}) which received none of the nutrients. Application of N along with others (P, K and B) up to certain level might have favoured in increased growth of the crop and attained the maximum height of the crop. Afroz *et al.* (2009) reported that the highest plant height (21.65 cm) was recorded in 135 kg N ha^{-1} and the lowest was noted in the control (no N) which is in agreement with the present findings. Similar findings on lettuce have been reported by Hochmuth *et al.* (1994).

Leaves per plant

Regarding numbers of leaves, a significant variation was also observed as influenced by different levels of N, P, K and B. The maximum number of leaves (19.75) was found in T_3 which was statistically identical to T_4 ($N_{150}P_{50}K_{100}B_{1.0}$), T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$), T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$), T_5 ($N_{200}P_{50}K_{100}B_{1.0}$) and T_{15} ($N_{100}P_{50}K_{100}B_{0.50}$) (Table 2). The minimum leaves per plant (9.60) were recorded in control (T_{18}). Lower level of N, P, K and B might have reduced the efficiency of plants in uptaking the nutrients for normal growth of plant. Tejaswini *et al.* (2012) found the maximum numbers of leaves per plant (19 and 16) in lettuce with 100 kg N ha^{-1}. Afroz *et al.* (2009) reported the maximum leaves $plant^{-1}$ (25.08) with application of 135 kg N ha^{-1} and the lowest from no nitrogen. All of these findings are very close to the present results.

Leaf size

Leaf size indicates the efficiency of photosynthesis, which has an important role in crop yield. The leaf size was significantly variable among the treatments (Table 2). The leaf size was increased with increase in nutrients level up to 100-50-100-1.0 kg ha^{-1} N-P-K-B, respectively and then decreased. The maximum size of leaf (380.70 cm^2) was recorded in T_4 where the minimum (198.40 cm^2) was found in the control ($N_0P_0K_0B_0$). Moniruzzaman (2002) reported that the maximum size of leaf (488.00 cm^2) was found in $N_{100}P_{50}$ and minimum (391.64 cm^2) was found in the control (N_0P_0), which are in agreement with the findings of our result.

Table 2. Plant height and leaf characters of lettuce as influenced by N, P, K and B application

Treatments	Plant height (cm)	Leaves plant^{-1} (no)	Leaf size (cm²)
T_1 ($N_0P_{50}K_{100}B_{1.0}$)	13.92 h	11.85 h	241.40 k
T_2 ($N_{50}P_{50}K_{100}B_{1.0}$)	18.30 ef	15.56 ef	305.50 gh
T_3 ($N_{100}P_{50}K_{100}B_{1.0}$)	22.50 ab	19.75 a	373.10 b
T_4 ($N_{150}P_{50}K_{100}B_{1.0}$)	23.27 a	18.50 ab	380.70 a
T_5 ($N_{200}P_{50}K_{100}B_{1.0}$)	22.04 a-c	18.29 a-c	361.70 c
T_6 ($N_{100}P_0K_{100}B_{1.0}$)	17.95 f	14.89 fg	295.50 i
T_7 ($N_{100}P_{25}K_{100}B_{1.0}$)	21.19 b-d	17.58 b-d	347.70 d
T_8 ($N_{100}P_{75}K_{100}B_{1.0}$)	19.97 de	16.57 b-f	327.60 f
T_9 ($N_{100}P_{100}K_{100}B_{1.0}$)	19.73 de	16.37 c-f	323.80 f
T_{10} ($N_{100}P_{50}K_0B_{1.0}$)	18.37 ef	15.15 b-f	302.10 h
T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$)	20.72 cd	17.00 b-e	340.10 e
T_{12} ($N_{100}P_{50}K_{150}B_{1.0}$)	18.83 ef	15.68 def	309.10 g
T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$)	18.61 ef	15.60 ef	303.40 gh
T_{14} ($N_{100}P_{50}K_{100}B_0$)	21.35 b-d	17.71 bc	350.10 d
T_{15} ($N_{100}P_{50}K_{100}B_{0.5}$)	21.81 a-c	18.20 a-c	358.10 c
T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$)	22.74 ab	18.42 ab	369.20 b
T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$)	22.27 a-c	18.30 a-c	362.50 c
T_{18} ($N_0P_0K_0B_0$)	13.20 h	9.60 i	198.40 l
T_{19} (CD_{10})	15.78 g	13.60 gh	262.70 j
CV (%)	3.53	4.84	0.82

Means followed by same letter (s) in a column do not differ significantly at 5% level of DMRT.

Canopy spread diameter

Canopy spread at harvest was significantly influenced by different levels of N, P, K and B. The maximum canopy spread diameter (29.90 cm) was found in T_4 ($N_{150}P_{50}K_{100}B_{1.0}$), which was statistically identical to T_3 ($N_{100}P_{50}K_{100}B_{1.0}$), T_5 ($N_{200}P_{50}K_{100}B_{1.0}$) and T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$) while the minimum value (14.20 cm) was recorded in the control (Table 3).

Dry matter content

The dry matter content (%) of lettuce at harvest was significantly influenced by different levels of N, P, K and B. Dry matter content of lettuce increased with increase in levels of N, P, K and B up to 200-50-100-1.0 kg N, P, K and B ha^{-1}. The highest dry matter (7.3%) was found in T_5 ($N_{200}P_{50}K_{100}B_{1.0}$) which was statistically similar with T_4 ($N_{150}P_{50}K_{100}B_{1.0}$), T_9 ($N_{100}P_{100}K_{100}B_{1.0}$), T_3 ($N_{100}P_{50}K_{100}B_{1.0}$) and T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$). On the contrary, the lowest dry matter content (5.25%) was recorded in the control (Table 3). Similar finding was also reported by Nafiu *et al*. (2011) where satisfactory growth and dry matter was recorded in 200 kg NPK ha^{-1}. Afroz *et al.* (2009) also reported that the highest dry matter content was noted in 135 kg N ha^{-1} and the lowest from no nitrogen. In present study the highest dry matter content was found in $N_{100}P_{50}K_{100}B_{1.0}$, which is similar to Afroz *et al.* (2009).

Leaf yield per plant and leaf yield per hectare

The leaf yield per plant was significantly influenced by the different levels of N, P, K and B (Table 3). The highest leaf weight per plant (231.10 g) was in T_3, which was statistically different from rest of the treatments. The lowest leaf weight (96.00 g $plant^{-1}$) was recorded in the control ($N_0P_0K_0B_0$). Boroujerdnia *et al*. (2007) reported the highest leaf yield with 120 kg N ha^{-1} which corroborated our findings. Similar results were also reported by Afroz *et al.* (2009) where as the highest leaf yield was found in 135 kg N ha^{-1}. Moniruzzaman (2002) reported that $N_{100}P_{50}$ showed the maximum leaf yield (422.67 g $plant^{-1}$), that was considered to be the best combination of nitrogen and phosphorus for maximizing leaf yield in lettuce, where the lowest yield (157.33 g $plant^{-1}$) was noted in N_0P_0. The variation in results might be due to difference of genotype or the growing environment or both.

There was a significant effect of nutrients on leaf yield of lettuce (Fig. 1). Results revealed that leaf weight increased with increase in nutrients levels up to 100-50-100-1.0 kg ha^{-1} N, P, K and B respectively, after that decreased at higher dose. Yield decrease at higher levels of nutrients might be due to the detrimental effects of the nutrients. The leaf yield ranged from 9.60 to 23.11 ton ha^{-1}. The highest leaf yield (23.11 ton ha^{-1}) was found in T_3 , which was statistically identical to T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$), T_4 ($N_{150}P_{50}K_{100}B_{1.0}$), T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$), T_5 ($N_{200}P_{50}K_{100}B_{1.0}$), T_{15} ($N_{100}P_{50}K_{100}B_{0.50}$), T_{14} ($N_{100}P_{50}K_{100}B_{0}$) and T_7 ($N_{100}P_{25}K_{100}B_{1.0}$). The lowest leaf yield (9.60 ton ha^{-1}) was recorded in the control. Increased rates of nutrients application up to certain level might have favored the growth and development of the crop and led to increased plant height; numbers of leaves per plant, leaf size, canopy cover and ultimately resulted in increase yield of lettuce leaves. The higher doses of nutrients might have created detrimental effect to give lower yield of the crop. Afroz *et al.* (2009) reported that the highest leaf yield (28.29 ton ha^{-1}) was found in 135 kg N ha^{-1}. The leaf yield per hectare was directly contributed by the number of leaves per plant and individual weight of plant. This finding is in conformity with the result of Sajjan *et al.* (1991) in lettuce.

Table 3. Canopy spread diameter, dry matter and leaf yield per plant of lettuce is influenced by different levels of N, P, K and B

Treatment	Canopy spread diameter (cm)	Dry matter (%)	Leaf yield plant^{-1} (g)
T_1 ($N_0P_{50}K_{100}B_{1.0}$)	17.37 j	6.10 de	130.20 n
T_2 ($N_{50}P_{50}K_{100}B_{1.0}$)	23.43 gh	6.48 b-e	188.50 i
T_3 ($N_{100}P_{50}K_{100}B_{1.0}$)	28.96 a-c	7.10 a-c	231.10 a
T_4 ($N_{150}P_{50}K_{100}B_{1.0}$)	29.90 a	7.20 ab	224.20 bc
T_5 ($N_{200}P_{50}K_{100}B_{1.0}$)	29.50 ab	7.30 a	219.60 de
T_6 ($N_{100}P_0K_{100}B_{1.0}$)	22.40 h	6.20 de	178.80 l
T_7 ($N_{100}P_{25}K_{100}B_{1.0}$)	26.45 def	6.50 b-e	211.10 f
T_8 ($N_{100}P_{75}K_{100}B_{1.0}$)	24.92 fg	7.00 b	198.90 h
T_9 ($N_{100}P_{100}K_{100}B_{1.0}$)	24.63 fg	7.20 ab	196.60 h
T_{10} ($N_{100}P_{50}K_0B_{1.0}$)	22.95 gh	6.60 b-e	183.00 k
T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$)	25.56 ef	6.70 b-e	206.40 g
T_{12} ($N_{100}P_{50}K_{150}B_{1.0}$)	23.51 gh	6.55 b-e	187.60 ij
T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$)	23.08 gh	6.01 e	184.20 jk
T_{14} ($N_{100}P_{50}K_{100}B_0$)	26.64 d-f	6.48 b-e	212.60 f
T_{15} ($N_{100}P_{50}K_{100}B_{0.5}$)	27.22 c-e	6.40 c-e	217.20 e
T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$)	28.00 a-d	7.05 a-c	226.50 b
T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$)	27.50 b-e	6.80 bc	221.90 cd
T_{18} ($N_0P_0K_0B_0$)	14.20 k	5.25 f	96.00 o
T_{19} (CD_{10})	19.98 i	6.72 b-e	156.00 m
C.V (%)	3.49	4.53	0.96

Means followed by same letter (s) in a column do not differ significantly at 5% level of DMRT.

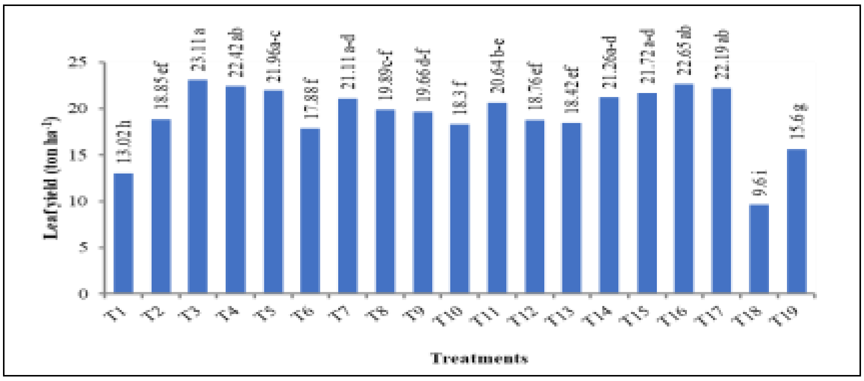

Fig. 1. Effect of N, P, K and B on leaf yield of lettuce.

Means placed on top of the bass followed by same letter(s) do not different significantly at 5% level of significance.

T_1 =$N_0P_{50}K_{100}B_{1.0}$; T_2 =$N_{50}P_{50}K_{100}B_{1.0}$; T_3 =$N_{100}P_{50}K_{100}B_{1.0}$; T_4 =$N_{150}P_{50}K_{100}B_{1.0}$; T_5 =$N_{200}P_{50}K_{100}B_{1.0}$; T_6 =$N_{100}P_0K_{100}B_{1.0}$; T_7 =$N_{100}P_{25}K_{100}B_{1.0}$; T_8 =$N_{100}P_{75}K_{100}B_{1.0}$; T_9 =$N_{100}P_{100}K_{100}B_{1.0}$; T_{10} =$N_{100}P_{50}K_0B_{1.0}$; T_{11} =$N_{100}P_{50}K_{50}B_{1.0}$; T_{12} =$N_{100}P_{50}K_{150}B_{1.0}$; T_{13} =$N_{100}P_{50}K_{200}B_{1.0}$; T_{14} =$N_{100}P_{50}K_{100}B_0$; T_{15}=$N_{100}P_{50}K_{100}B_{0.50}$; T_{16} =$N_{100}P_{50}K_{100}B_{1.50}$; T_{17} =$N_{100}P_{50}K_{100}B_{2.0}$; T_{18} =$N_0P_0K_0B_0$; T_{19} =CD_{10}

2. Seed yield of lettuce

Days to 50% flowering

Days to 50% flowering of lettuce plants were significantly influenced by different levels of N, P, K and B application. The plants took minimum days (117.30) for 50% flowering in T_3, which was statistically identical to T_7 and T_{16} (Table 4). The maximum period (121.50 days) was taken to 50% flowering in T_{18} followed by T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$) and T_{10} ($N_{100}P_{50}K_0B_{1.0}$). Similar result was also reported by Paul (2009) where control ($N_0P_0K_0$) showed the highest period for 50% flowering and the lowest period was noted in $N_{100}P_{50}K_{100}$ kg ha^{-1} in sweet pepper. The result is in agreement with the findings of our study. This might be due to optimum doses of fertilizer that enhances metabolic and physiological activities and promoted the vegetative and reproductive growth.

Table 4. Effect of N, P, K and B on days to 50% flowering, days to seed maturity and branches per plant of lettuce

Treatments	Days to 50% Flowering	Days to seed maturity	Branches per plant (no.)
T_1 ($N_0P_{50}K_{100}B_{1.0}$)	120.10 b-e	142.40 b-e	24.36 e
T_2 ($N_{50}P_{50}K_{100}B_{1.0}$)	120.20 b-e	141.50 b-e	30.00 d
T_3 ($N_{100}P_{50}K_{100}B_{1.0}$)	117.30 j	139.50 f	40.66 a
T_4 ($N_{150}P_{50}K_{100}B_{1.0}$)	119.50 d-g	143.00 b-d	41.50 a
T_5 ($N_{200}P_{50}K_{100}B_{1.0}$)	120.50 a-d	143.50 a-c	41.60 a
T_6 ($N_{100}P_0K_{100}B_{1.0}$)	118.50 g-i	141.40 c-e	35.50 bc
T_7 ($N_{100}P_{25}K_{100}B_{1.0}$)	117.60 i-j	139.70 f	37.50 bc
T_8 ($N_{100}P_{75}K_{100}B_{1.0}$)	119.50 d-g	141.30 c-e	36.38 bc
T_9 ($N_{100}P_{100}K_{100}B_{1.0}$)	120.50 a-d	143.50 a-c	35.60 bc
T_{10} ($N_{100}P_{50}K_0B_{1.0}$)	120.80 ab	143.80 ab	34.50 c
T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$)	121.00 ab	143.00 b-d	36.50 bc
T_{12} ($N_{100}P_{50}K_{150}B_{1.0}$)	119.20 e-g	142.50 b-d	34.42 c
T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$)	120.60 a-c	143.80 ab	35.66 bc
T_{14} ($N_{100}P_{50}K_{100}B_0$)	118.60 fg	140.90 de	38.60 ab
T_{15} ($N_{100}P_{50}K_{100}B_{0.5}$)	119.50 d-g	141.80 b-e	37.00 bc
T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$)	117.90 h-j	140.10 e	37.50 bc
T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$)	119.50 d-g	142.80 b-d	36.50 bc
T_{18} ($N_0P_0K_0B_0$)	121.50 a	144.20 a	15.20 f
T_{19} (CD_{10})	119.60 e-f	141.50 b-e	28.14 d
C.V (%)	0.35	0.65	3.73

Means followed by same letter (s) in a column do not differ significantly at 5% level of DMRT.

Days to seed maturity

Days to seed maturity of lettuce were significantly variable among different levels of N, P, K and B. The maximum period for seed maturity (144.20 days) was found in T_{18} closely followed by T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$), T_{10} ($N_{100}P_{50}K_0B_{1.0}$), T_5 and T_9 ($N_{100}P_{100}K_{100}B_{1.0}$) while it was minimum (139.50 days) in T_3 followed by T_7 (Table 4). Moniruzzaman (2002) reported that the maximum period for days to seed maturity was observed in $N_{150}P_0$ and the minimum was found in $N_{150}P_{50}$, which is in agreement with the present findings. This might be also due to optimum doses of fertilizer that enhance the vegetative and reproductive growth.

Branches per plant

The number of branches per plant was also varied significantly due to the application of N, P, K and B (Table 4). T_5 ($N_{200}P_{50}K_{100}B_{1.0}$) showed the highest number of branches per plant (41.60) followed by T_4, T_3 and T_{14}. The lowest number of branches per plant (15.20) was recorded in the control. Number of branches increased up to 200 kg N ha^{-1} application. But application of P, K and B at the rate of 50, 100 and 1.00 kg ha^{-1}, respectively also significantly increased number of branches per plant beyond which it decreased significantly. Similar results were also reported by Ahammed (2009), where the maximum branches $plant^{-1}$ was recorded in N, P, K and S at the rate of 150, 25, 50 and 4.00 kg ha^{-1}, respectively in stem amaranth. Faiza *et al.* (2002) also reported maximum branches per plant with the application of 150 kg N ha^{-1}. Sharma (1995) also reported that the maximum branches per plant were noted at 75 kg P_2O_5 and 100 kg K_2O ha^{-1}.

Capsules per plant

The capsules per plant were significantly influenced by different levels of N, P, K and B. The number of capsules per plant ranged from 324.50 to 582.20, having the highest number (582.20) in T_3 closely followed by T_8 ($N_{100}P_{75}K_{100}B_{1.0}$). The minimum number of capsules per plant (324.50) was recorded in the control (Table 5). Capsules per plant increased significantly up to 100, 50, 100 and 1.00 kg ha^{-1} of N, P, K and B application respectively, beyond that capsules per plant decreased significantly. Similar results were also found by Sajjan *et al*. (1992) in lettuce.

Seeds per capsule and 1000 seed weight

Seeds per capsule were significantly influenced by the different levels of N, P, K and B (Table 5). The highest average seeds $capsule^{-1}$ (11.96) was recorded from the plants of T_3 ($N_{100}P_{50}K_{100}B_{1.0}$) which was statistically similar with T_8 ($N_{100}P_{75}K_{100}B_{1.0}$) and T_9 ($N_{100}P_{100}K_{100}B_{1.0}$). On the other hand, the lowest seeds $capsule^{-1}$ (9.20) was noticed in T_{18} ($N_0P_0K_0B_0$). The above results clearly indicated that application of N, P, K and B dose up to $N_{100}P_{50}K_{100}B_{1.0}$ increased seed formation of lettuce and further increment in the dose of N, P, K and B in lettuce seed production declined the seed formation. Similar results also reported by Moniruzamman (2002). But no significant differences were found in 1000 seed weight although it ranged from 1.01 to 1.08 g.

Table 5. Effect of N, P, K and B on capsules per plant, seeds per capsule and 1000 seed weight (g) of lettuce

Treatments	Capsules per plant (no.)	Seeds per capsules (no.)	1000 seeds weight (g)
T_1 ($N_0P_{50}K_{100}B_{1.0}$)	328.70 g	9.50 de	1.03
T_2 ($N_{50}P_{50}K_{100}B_{1.0}$)	460.30 e	9.80 cde	1.01
T_3 ($N_{100}P_{50}K_{100}B_{1.0}$)	582.20 a	11.96 a	1.07
T_4 ($N_{150}P_{50}K_{100}B_{1.0}$)	548.10 b	11.01 b	1.01
T_5 ($N_{200}P_{50}K_{100}B_{1.0}$)	545.60 b	10.78 bc	1.07
T_6 ($N_{100}P_0K_{100}B_{1.0}$)	448.30 e	10.25 bcd	1.07
T_7 ($N_{100}P_{25}K_{100}B_{1.0}$)	533.70 bc	10.27 bcd	1.07
T_8 ($N_{100}P_{75}K_{100}B_{1.0}$)	553.60 ab	11.20 ab	1.06
T_9 ($N_{100}P_{100}K_{100}B_{1.0}$)	536.70 bc	11.08 ab	1.08
T_{10} ($N_{100}P_{50}K_0B_{1.0}$)	494.60 d	10.20 bcd	1.04
T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$)	520.60 b-d	10.53 bc	1.05
T_{12} ($N_{100}P_{50}K_{150}B_{1.0}$)	525.10 b-d	10.80 bc	1.04
T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$)	510.00 cd	10.75 bc	1.05
T_{14} ($N_{100}P_{50}K_{100}B_0$)	529.80 bc	10.50 bc	1.05
T_{15} ($N_{100}P_{50}K_{100}B_{0.5}$)	541.40 bc	10.91 b	1.05
T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$)	546.20 b	10.80 bc	1.05
T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$)	532.10 bc	10.60 bc	1.03
T_{18} ($N_0P_0K_0B_0$)	324.50 g	9.20 e	1.05
T_{19} (CD_{10})	395.60 f	9.30 de	1.08
C.V (%)	2.71	3.75	2.78

Means followed by same letter (s) in a column do not differ significantly at 5% level of DMRT.

Seed yield

The seed yield was significantly variable among different treatments. The seed yield of lettuce ranged from 240.5 to 57.5 kg ha^{-1}. The highest seed yield (571.50 kg ha^{-1}) was found in T_3, which was statistically identical to T_8, T_9, T_4 and T_{16}

($N_{100}P_{50}K_{100}B_{1.50}$). The lowest seed yield (240.50 kg ha^{-1}) was recorded in the control. It was observed that the seed yield of lettuce increased with increase in nutrient levels upto 100-50-100-1.0 kg ha^{-1} of N, P, K and B, respectively beyond that seed yield was decreased (Figure 2). Sajjan *et al.*, (1992) and Ahammed (2009) reported that significant increase in number of branches per plant, number of capsules per plant, number of seeds per capsules and 1000 seeds weight contributed to high seed yield per hectare. The seed yield per hectare in different treatments varied possibly due to the effects of different nutrients.

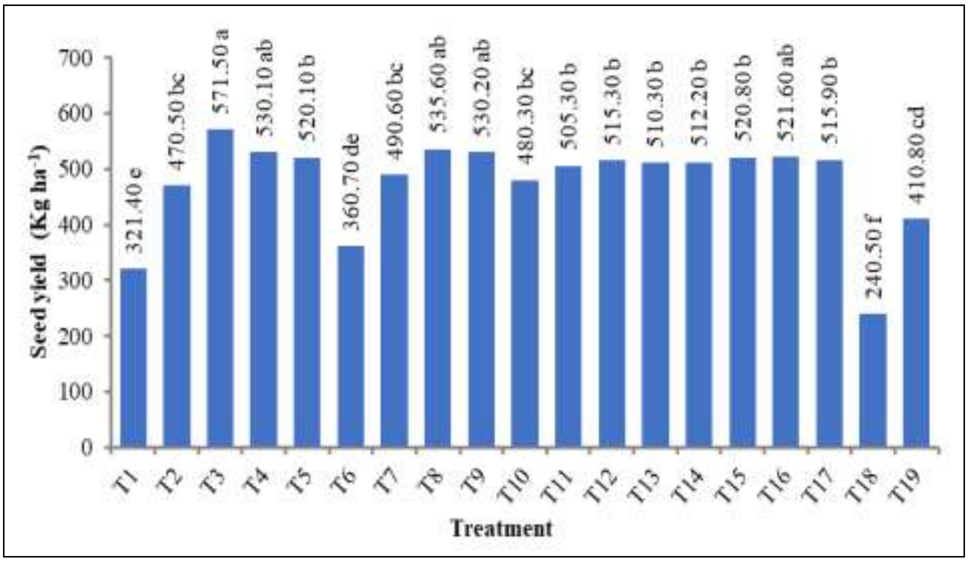

Fig. 2. Effect of NPK and B on seed yield of lettuce.

Means placed on top of the bass followed by same letter(s) do not different significantly at 5% level of significance.

T_1 $=N_0P_{50}K_{100}B_{1.0}$; T_2 $=N_{50}P_{50}K_{100}B_{1.0}$; T_3 $=N_{100}P_{50}K_{100}B_{1.0}$; T_4 $=N_{150}P_{50}K_{100}B_{1.0}$; T_5 $=N_{200}P_{50}K_{100}B_{1.0}$; T_6 $=N_{100}P_0K_{100}B_{1.0}$; T_7 $=N_{100}P_{25}K_{100}B_{1.0}$; T_8 $=N_{100}P_{75}K_{100}B_{1.0}$; T_9 $=N_{100}P_{100}K_{100}B_{1.0}$; T_{10} $=N_{100}P_{50}K_0B_{1.0}$; T_{11} $=N_{100}P_{50}K_{50}B_{1.0}$; T_{12} $=N_{100}P_{50}K_{150}B_{1.0}$; T_{13} $=N_{100}P_{50}K_{200}B_{1.0}$; T_{14} $=N_{100}P_{50}K_{100}B_0$; $T_{15}=N_{100}P_{50}K_{100}B_{0.5}$; T_{16} $=N_{100}P_{50}K_{100}B_{1.5}$; T_{17} $=N_{100}P_{50}K_{100}B_{2.0}$; T_{18} $=N_0P_0K_0B_0$; T_{19} $=CD_{10}$.

Relationship between nutrient levels and leaf yield of lettuce

The quadratic relationship was found between the leaf yield of lettuce and applied nutrients (N, P, K and B). From the regression equation $y= 0.0005x^2 + 0.1431x + 13.0777$; $y= 0.013x2 + 3.546x + 325.5$; $y= 0.001x2 + 0.148x + 18.12$; $y= 0.044x2 + 5.963x + 365.5$ the optimum dose of N, P, K and B calculated to be 143, 74, 95 and 1.3 k ha^{-1}, respectively (Table 6). The maximum yield for optimum dose of N, P, K and B was 23.1, 23.0, 23.1 and 23.1 ton ha^{-1}, respectively.

Table 6. Response function of leaf yield of lettuce to N, P, K and B application

Nutrient	Regression equation	R^2 value	Optimum dose (kg ha^{-1})	Obtainable maximum yield (ton ha^{-1})
N	$y= 0.0005x^2 + 0.1431x + 13.0777$	$R^2= 0.9802$	143	23.1
P	$y= 0.001x^2 + 0.148x + 18.12$	$R^2= 0.739$	74	23.0
K	$y= 0.0004x^2 + 0.0663x + 18.434$	$R^2= 0.643$	95	23.1
B	$y= 1.054x^2 + 2.666x + 21.10$	$R^2= 0.816$	1.3	23.1

Relationship between nutrient levels and seed yield of lettuce

Similarly, the quadratic relationship was found between the seed yield of lettuce and applied nutrients (N, P, K and B). From the regression equation $y= 0.013x^2 + 3.546x + 325.5$; $y= 0.044x^2 + 5.963x + 365.5$; $y= 0.005x^2 + 1.182x + 476.4$; $y= 36.91x^2 + 75.46x + 508.3$ the optimum dose of N, P, K and B calculated to be 136.4, 67.8, 188.0 and 1.0 kg ha^{-1}, respectively (Table 7). The maximum seed yield for optimum dose of N, P, K and B was 571.5, 571.5, 571.5 and 571.5 kg ha^{-1}, respectively.

Table 7. Response function of seed yield of lettuce to N, P, K and B application

Nutrient	Regression equation	R^2 value	Optimum dose (kg ha^{-1})	Obtainable maximum yield (kg ha^{-1})
N	$y= 0.013x^2 + 3.546x + 325.5$	$R^2= 0.956$	136.4	571.5
P	$y= 0.044x^2 + 5.963x + 365.5$	$R^2= 0.951$	67.8	571.5
K	$y= 0.005x^2 + 1.182x + 476.4$	$R^2= 0.636$	118.0	571.5
B	$y= 36.91x^2 + 75.46x + 508.3$	$R^2= 0.503$	1.0	571.5

3. Economic evaluation of fertilizer use

Leaf yield

The economic evaluation based on different treatment combination of N, P, K, B and cow dung in relation to the leaf yield of lettuce is presented in Table 8. It was observed that the highest production cost (Tk. 47810 ha^{-1}) was found in T_9 and this is due to higher cost for TSP fertilizer. The highest benefit cost ratio (BCR) (7.50) was noted in T_3 (100-50-100-1.00 kg NPKB ha^{-1}) and this might be due to lower cost of fertilizer and highest gross margin (Tk. 305825 ha^{-1}). The lowest BCR (4.35) was found in T_1 (0-50-100-1.00 kg NPKB ha^{-1}) due to higher cost of fertilizer and lower gross return. A similar finding was found by Islam *et al.* (2007).

Table 8. Economic evaluation based on different levels of NPKB in relation to leaf yield of lettuce

N-P-K-B Kg ha^{-1}	Leaf yield (ton ha^{-1})	Total cost of production (Tk ha^{-1})	Gross return (Tk ha^{-1})	Gross margin (Tk ha^{-1})	BCR
T_1 ($N_0P_{50}K_{100}B_{1.0}$)	13.02	36845	195300	158810	4.35
T_2 ($N_{50}P_{50}K_{100}B_{1.0}$)	18.85	38655	282750	244095	6.34
T_3 ($N_{100}P_{50}K_{100}B_{1.0}$)	23.11	40825	346650	305825	7.50
T_4 ($N_{150}P_{50}K_{100}B_{1.0}$)	22.42	42995	336300	293305	6.82
T_5 ($N_{200}P_{50}K_{100}B_{1.0}$)	21.96	45162	329400	284235	6.29
T_6 ($N_{100}P_0K_{100}B_{1.0}$)	17.88	33840	268200	234360	6.93
T_7 ($N_{100}P_{25}K_{100}B_{1.0}$)	21.11	37332.50	316650	279000	7.47
T_8 ($N_{100}P_{75}K_{100}B_{1.0}$)	19.89	44317.50	298350	253080	5.71
T_9 ($N_{100}P_{100}K_{100}B_{1.0}$)	19.66	47810	294900	245820	5.14
T_{10} ($N_{100}P_{50}K_0B_{1.0}$)	18.30	35825	274500	238040	6.64
T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$)	20.64	38325	309600	270640	7.06
T_{12} ($N_{100}P_{50}K_{150}B_{1.0}$)	18.76	43325	281400	237440	5.48
T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$)	18.42	45825	276300	229840	5.02
T_{14} ($N_{100}P_{50}K_{100}B_0$)	21.26	38325	318900	279940	7.30
T_{15} ($N_{100}P_{50}K_{100}B_{0.5}$)	21.72	39575	325800	285590	7.21
T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$)	22.65	42075	339750	297040	7.06
T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$)	22.19	43325	332850	288890	6.67
T_{18} ($N_0P_0K_0B_0$)	9.60	22000	144000	122000	5.55
T_{19} (CD_{10})	15.60	32000	234000	202000	6.31

Price of input: Urea: Tk. 20 kg^{-1}; TSP: Tk. 27.50 kg^{-1}; MoP: Tk. 25 kg^{-1}; Boric acid: Tk. 500 kg^{-1} and Cow dung: Tk. 1.00 kg^{-1}. **price of output:** Lettuce: Tk. 15.00 kg^{-1}

Seed yield

The economic evaluation based on different treatment combination of N, P, K, B and cow dung in relation to the seed yield of lettuce is presented in Table 9. Treatment T_9 showed the highest production cost (Tk. 47810 ha^{-1}) followed by T_{13} and T_5. The highest benefit cost ratio (BCR) (70.0) was recorded in T_3 (100-50-100-1 kg NPKB ha^{-1}), because of lower cost of fertilizer and highest gross margin (Tk. 2857500 ha^{-1}). The lowest benefit cost ratio (43.6) also recorded in

100-50-100-1 kg NPKB ha^{-1} and this is due to higher fertilizer cost and lower gross return. Similar finding was found by Islam *et al.* (2007).

Table 9. Economic evaluation based on different levels of NPKB in relation to seed yield of lettuce

N-P-K-B Kg ha^{-1}	Seed yield (kg ha^{-1})	Total cost of production (Tk. ha^{-1})	Gross return (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
T_1 ($N_0P_{50}K_{100}B_{1.0}$)	321.40	36845	1607000	1570155	43.6
T_2 ($N_{50}P_{50}K_{100}B_{1.0}$)	470.50	38655	2352500	2313845	60.9
T_3 ($N_{100}P_{50}K_{100}B_{1.0}$)	571.50	40825	2857500	2816675	70.0
T_4 ($N_{150}P_{50}K_{100}B_{1.0}$)	530.10	42995	2650500	2607505	61.6
T_5 ($N_{200}P_{50}K_{100}B_{1.0}$)	520.10	45162	2600500	2555338	57.6
T_6 ($N_{100}P_0K_{100}B_{1.0}$)	360.70	33840	1803500	1769660	53.3
T_7 ($N_{100}P_{25}K_{100}B_{1.0}$)	490.60	37332.5	2453000	2415667.5	65.7
T_8 ($N_{100}P_{75}K_{100}B_{1.0}$)	535.60	44317.5	2678000	2633682.5	60.4
T_9 ($N_{100}P_{100}K_{100}B_{1.0}$)	530.20	47810	2651000	2603190	55.4
T_{10} ($N_{100}P_{50}K_0B_{1.0}$)	480.30	35825	2401500	2365675	67.0
T_{11} ($N_{100}P_{50}K_{50}B_{1.0}$)	505.30	38325	2526500	2488175	65.9
T_{12} ($N_{100}P_{50}K_{150}B_{1.0}$)	515.30	43325	2576500	2533175	59.5
T_{13} ($N_{100}P_{50}K_{200}B_{1.0}$)	510.30	45825	2551500	2505675	55.7
T_{14} ($N_{100}P_{50}K_{100}B_0$)	512.20	38325	2561000	2522675	66.8
T_{15} ($N_{100}P_{50}K_{100}B_{0.5}$)	520.80	39575	2604000	2564425	65.8
T_{16} ($N_{100}P_{50}K_{100}B_{1.5}$)	521.60	42075	2608000	2565925	62.0
T_{17} ($N_{100}P_{50}K_{100}B_{2.0}$)	515.90	43325	2579500	2536175	59.5
T_{18} ($N_0P_0K_0B_0$)	240.50	22000	1202500	1180500	54.7
T_{19} (CD_{10})	410.80	32000	2054000	2022000	64.2

Price of input: Urea: Tk. 20 kg^{-1}; TSP: Tk. 27.50 kg^{-1}; MoP: Tk. 25 kg^{-1}; Boric acid: Tk. 500 kg^{-1} and Cow dung: Tk. 1.00 kg^{-1}. **price of output:** Lettuce seed: Tk. 5000.00 kg^{-1}

3. Conclusion

The different levels of N, P, K and B showed significant effect on the leaf and seed yield of lettuce. Treatment T_3 ($N_{100}P_{50}K_{100}B_{1.0}$) was considered as the best combination of N, P, K and B application producing the maximum leaf and seed yield of lettuce in respect of economic profitability with the highest gross margin and BCR both for leaf (Tk. 305825 ha^{-1} and 7.50) and seed (Tk. 2816675 ha^{-1} and 70.0). But, from regression equation, the calculated optimum nutrient doses for maximum leaf and seed yield are $N_{143}P_{74}K_{95}B_{1.3}$ and $N_{136.4}P_{67.8}K_{188.0}B_{1.0}$ kg ha^{-1}

respectively that could be recommended as the optimum doses of N, P, K and B to achieve higher leaf and seed production of lettuce in Salna soils of Bangladesh.

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ADOPTION AND PROFITABILITY OF BARI MALTA-1 IN SELECTED AREAS OF BANGLADESH

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Abstract

The study was conducted in three malta growing districts namely Khagrachori, Pirojpur and Chapai Nawabganj during January-March 2018. An attempt was made to assess the adoption status of BARI Malta-1 (sweet orange), its farm level profitability, problems and the impacts of malta cultivation on the livelihood of farmers. A total of 180 farmers, 60 farmers from each district were randomly selected for this study. The study revealed that 91% farmers adopted BARI Malta-1 in their gardens. Higher yield, profitability, sweetness, and less insect-pests infestations were the major reasons for choosing BARI Malta-1 at farm level. Farmers did not follow the recommended doses of manures and fertilizers due to lack of adequate knowledge on recommended doses. The establishment cost of a malta garden was Tk. 7,02,650 per hectare. The highest yield (19.6 t/ha) and gross return (Tk. 15,68,000/ha) were obtained from 5th to 10th year gardens. The lowest return (Tk. 8,28,160/ha) was reported in the 3rd year garden. Scarcity of saplings, un-attractive colour, and lack of technical know-how were the major problems to BARI Malta-1 cultivation. The study suggested availability of saplings, hands-on training to the farmers, and affordable price of different input for higher adoption of this variety.

1. Introduction

Bangladesh is predominantly an agricultural country where agriculture sector plays a vital role in overall economic development of Bangladesh. This sector contributes a lot to the country's GDP (15%), provides employment for about 41% of the labour force and supplies raw materials to the agro-based industries (BBS, 2018). The climatic condition and ecological factors of Bangladesh is very much favorable for various fruits cultivation. Among various citrus fruits, malta (sweet orange) is a favorite fruit in Bangladesh. Orange market in Bangladesh consists almost entirely of imported products. The country imports a huge amount of mandarin and malta from China, India, Bhutan, Pakistan and many other countries for meeting its domestic demand. Available statistics shows that the share of imports in total orange consumption was 92.4% (43.6 thousand MT valuing 16.5 million USD) in 2010 (https://app.indexbox.io/report/ 080510/50/).

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Besides, Bangladesh also imported 30.92 thousand litre of orange juice valuing Tk. 6.521 million in 2018-19 (BBS, 2019).

In Bangladesh Sylhet, Hobiganj, Moulovibazar, Chottogram, Chottogram hill tract, Cox's Bazar, hilly and well drained areas of Panchagarh, Thakurgaon, Tangail, and Gazipur districts and some parts of Mymensingh, Narsingdi, Sherpur, Netrokona districts, and some southern and northern parts of the country have potential to bring under citrus fruit cultivation. It is possible to grow sweet orange and mandarin orange commercially to fulfill the national demand and save foreign exchange by eliminating the problems by developing suitable varieties and improved management techniques. Bangladesh Agricultural Research Institute (BARI) has developed a malta variety namely BARI Malta-1 since 2003. The Department of Agricultural Extension (DAE) has been involved in dissemination of this variety through its countrywide networks. Due to collaborative extension works with different agencies, BARI Malta-1 variety is cultivating all over the country.

The adequate farm level socioeconomic data and information and farmers' feedback about this variety are unknown to the researchers and policy makers. Kaysar et al., (2017) conducted a socioeconomic study on mandarin cultivation in selected areas of Bangladesh. Therefore, an attempt was made to assess the status of farm level adoption of BARI Malta-1 cultivation, its profitability, constraints to its cultivation and its adoption impacts on farmer's livelihood in Bangladesh. The specific objectives of this study were as follows.

a) To assess the adoption of BARI Malta-1 at the farm levels;
b) To find out the factors affecting their adoptions and sustainability;
c) To estimate the profitability of BARI Malta-1 cultivation; and
d) To find out the problems of BARI Malta-1 cultivation at farm level.

2. Materials and Methods

2.1 Sampling Technique and Sample Size

Purposive random sampling technique was used to select the sample respondents. In the first stage of sampling, three malta growing districts namely Khagrachori, Pirojpur and Chapai Nawabganj were selected purposively based on area coverage and production of malta. A total of 180 samples taking 60 farmers from each district were randomly selected for this study. Data were collected by the experienced field investigators with direct supervision of the researchers using a pre-tested interview schedule.

2.2 Analytical Techniques

Data were categorized according to the year of gardens like 1st year, 2nd year, 3rd year, 4th year, 5-10th year and above 10 years. Tabular methods of analysis using descriptive statistics were used in presenting the results of the study. The following equations were used to calculate profitability of BARI Malta-1 cultivation:

Gross return = GRij = YijPij

Net return = GRij – TCij

Gross margin = GRij – VCij

Where,

GRij = Gross return (Tk./ha)

Pij = Price (Tk./ha of j^{th} crop received by i^{th} farmer)

Yij = Quantity produced (kg/ha)

TC_{ij} = Total cost of j^{th} crop for i^{th} farmer (Tk/ha)

VC_{ij} = Variable cost of j^{th} crop for i^{th} farmer (Tk/ha)

2.3 Analysis of Returns to Investment

The profitability of malta production was also measured by calculating net present value (NPV), benefit cost ratio (BCR) and internal rate of return (IRR) of the malta orchard. The discount rate was specified by assuming the opportunity cost of capital which is 12% for most of the developing countries (Gittinger, 1982).

2.4 Factors of Adoption of BARI Malta-1 Technology

The following Probit model was used to determine the factors of adoption of BARI Malta-1 technology at farm level. The model was as follows:

$$Ai = a + \beta iXi + \ldots\ldots\ldots\ldots\ldots\ldots + Ui$$

Where,

Ai = Farmers adopting BARI Malta-1 (If adopt = 1; Otherwise = 0)

a = Intercept

Xi = Explanatory variables (socioeconomic characteristics)

Bi = Coefficients of the respective factors

Ui = Error term

The explanatory variables were as follows:

X_1 = Age of the respondent (year)

X_2 = Education (Year of schooling)

X_3 = Farm size (decimal)

X_4 = Family labour (No./ha)

X_5 = Training received on BARI Malta-1 (No. in lifetime)

X_6 = Training received on agriculture (No. in lifetime)

X_7 = Availability of saplings (Score)
X_8 = Availability of suitable land (Score)
X_9 = Influence of neighbouring farmers (Score)
X_{10}= Influence of extension personnel (Score)
X_{11}= Societal membership (Score)

3. Results and Discussion

3.1 Socio-economic Profile of the Farmers

Education: There is a positive relationship between education and agricultural productivity and technology adoption (Okpachu et al., 2014; Asfaw and Admassie, 2004; Appleton and Balihuta, 1996). So, farmer's education is expected to play crucial role in increasing farming output and adoption of new technologies. Adoption of new technology and efficiently use of farm resources to make maximum profit there is no alternative of farmers education. The farmers were categorized into (1) Can't read & write, (2) Primary, (3) Secondary, (4) Higher secondary, and (5) Degree & above groups (Table 1). It was observed that 8% of adopters and 20% of non-adopters did not have any formal education. The highest 45% of adopters have secondary level education followed by 23% have primary level, 15% have higher secondary level, and 7% have degree and above level education. On the other hand, 36% of non-adopters have primary level education followed by 30% secondary level, 11% higher secondary, and 4% have degree & above level education.

Table 1. Percent distribution of farmers by literacy levels

Literacy level	Khagrachori	Pirojpur	Chapai Nawabganj	All area
A. Adopter				
Can't read & write	12	5	8	8
Primary	31	14	25	23
Secondary	47	47	41	45
Higher secondary	8	22	16	15
Degree & above	2	12	8	7
B. Non-adopter				
Can't read & write	22	17	21	20
Primary	38	31	38	36
Secondary	34	31	24	30
Higher secondary	6	14	12	11
Degree & above	-	7	5	4

Source: Field survey 2018

Land holding: Farming activities mainly depend on land holding of the farmers. Table 2 reveals that farm size of adopters and non-adopters were 2.36 ha and 1.59 ha respectively. The land holdings of the adopting farmers of Khagrachori was higher than that of farmers of Pirojpur and Chapai Nawabganj districts.

Table 2. Category of land and farm size (ha) of the respondent farmers

Land category	Khagrachori	Pirojpur	Chapai Nawabganj	All area
A. Adopter				
1. Own land	0.680	0.405	0.348	0.47
2. Rented in	0.243	0.138	0.162	0.18
3. Rented out	0.182	0.101	0.146	0.14
4. Mortgaged in	0.304	0.085	0.121	0.17
5. mortgaged out	0.227	0.093	0.097	0.13
6. Homestead	0.101	0.097	0.101	0.10
7. Malta orchard	0.445	0.202	0.223	0.29
8. Other orchard	1.065	0.482	0.429	0.65
9. Fallow land	0.243	0.109	0.081	0.14
10. Pond	0.000	0.081	0.097	0.05
Farm size (ha)	**3.490**	**1.794**	**1.806**	**2.36**
A. Non-adopter				
1. Own land	0.421	0.202	0.308	0.31
2. Rented in	0.162	0.085	0.142	0.13
3. Rented out	0.097	0.057	0.154	0.10
4. Mortgaged in	0.182	0.105	0.113	0.13
5. mortgaged out	0.158	0.097	0.138	0.13
6. Homestead	0.061	0.069	0.081	0.07
7. Malta orchard	0.121	0.000	0.000	0.04
8. Other orchard	0.745	0.271	0.324	0.44
9. Fallow land	0.198	0.182	0.142	0.17
10. Pond	0.000	0.093	0.061	0.05
Farm size (ha)	**2.146**	**1.162**	**1.462**	**1.59**

Source: Field survey 2018

Influencing persons in variety adoption: At the beginning stage of adopting of BARI Malta-1, most farmers were influenced by different persons at different levels. Table 3 shows that the overall influence of SAAO in adopting BARI

Malta-1 was higher than the influence of others. Akter et al. (2010) also found that the influence of SAAO in adopting BARI groundnut was highly significant. Neighboring farmers and AO also influenced farmers in adopting BARI Malta-1 in the study areas.

Table 3. Distribution of adopters by influencing persons

Persons	Level of influence (%)				
	Very high	High	Medium	Low	No influence
1. Family member	-	-	8	16	76
2. Neighboring farmer	15	41	27	5	12
3. SAAO	82	6	-	4	8
4. Agriculture Officer	13	18	13	42	16
5. IPM/ICM club			14	13	73
6. Scientists of OFRD	-	-	-	7	93

Source: Field survey 2018

Reasons for choosing BARI Malta-1: Respondent farmers adopted BARI Malta-1 for its numerous attributes such as higher yield, sweetness, higher demand in the market, highly profitable, availability of saplings, and less attack of insect-pests. Table 4 depicts that the higher yield of BARI Malta-1 was the first attribute that influenced farmers to adopt the variety.

Table 4. Reasons for choosing BARI Malta-1 variety adoption

Reasons	Rank order			
	Khagrachori	Pirojpur	Capai Nawabganj	All area
1. Higher yield	1	1	1	1
2. Highly profitable	2	3	2	2
3. Higher demand	4	2	4	3
4. Very tasty	3	4	3	4
5. Less attack of insects and pests	5	5	5	5
6. Attractive color	6	6	6	6

Source: Field survey 2018

Level of extension contact: Extension contact play significant role in improved technology adoption at farm level (Islam et al., 2013; Miah et al., 2015). DAE is the key agent of Bangladesh government to dissemination of crop related agricultural technologies from research organization to farmer's field. Table 5 reveals that the adopters of BARI Malta-1 had frequent contact with the extension personnel and neighboring farmers and their level of contacts were more than non-adopters in the study areas. It was opined that about 49% farmers contacted with extension personnel regarding malta cultivation which was much higher than that of non-adopters. Contact with mass media (i.e. radio, television, newspaper) was also higher than non-adopters in the study areas.

Table 5. Level of extension contact of malta farmers with different extension medias

Extension medias	Farmer's responses (%)			
	Frequently	Often	Rarely	Never
A. Adopter				
Extension personnel	27	49	18	6
Neighbor farmer	23	58	17	2
Demonstration plot	3	7	14	76
Participating agril. fair	-	3	13	84
Television	-	2	4	94
Attend in the field day		8	18	74
Research organization visit	-	4	10	86
Radio	-	6	8	86
News paper	-	-	4	96
Agriculture booklet/leaflet	-	-	1	99
B. Non-adopter				
Extension personnel	18	34	23	25
Neighbor farmer	17	44	7	32
Demonstration plot	6	29	18	47
Participating agril. fair	2	3	11	84
Television	2	4	17	77
Attend in the field day	-	-	6	94
Research organization visit	--	12	17	71
Radio	-	-	-	100
News paper	-	-	-8	92
Agriculture booklet/leaflet	-	-	-	100

Training received: Technological knowledge dissemination training plays crucial role in increasing skills on production and related activities. Yokouchi and Saito (2016) found that training had significant influence on the adoption of NERICA upland rice varieties in Benin. Table 6 revealed that 40% BARI Malta-1 adopters and 91% non-adopters did not receive any training on malta cultivation. More than half of the adopters received 1-2 times training in their lifetime. DAE was the key agency to provide the training on malta cultivation at farmers level. More than two training was received by 9% non-adopters only.

Table 6. Training received by the farmers on malta cultivation

No. of training received	Farmer's responses (%)			
	Khagrachori	Pirojpur	Capai Nawabganj	All area
A. Adopter	n=40	n=40	n=40	n=120
No training	35	38	46	40
1-2 Nos.	42	56	54	51
3-4 Nos.	17	6	-	8
5-6 Nos.	6	-	-	2
Total	100	100	100	100
B. Non-adopter				
No training	84	94	96	91
1-2 Nos.	16	6	4	9
3-4 Nos.	-	-	-	-
5-6 Nos.	-	-	-	-
Total	100	100	100	100

Distribution of income from BARI Malta-1 production: Adopting farmers distributed their income from BARI Malta-1 cultivation in various way such as education of their children, daily food consumption, buying land, farm expenditure etc. Table 7 revealed that the highest (21%) income was spent on farm level expenditure. About 13% of income was spent on education of their children and 28% of income was spent on daily food consumption. They also used their income on purchase of furniture (6%), animal feed (10%), and savings at bank (5%), family recreation (2%), buying agricultural equipment (2%), and many other purposes (9%).

Table 7. Percent distribution of malta cultivation income on various household purposes

Item	Khagrachori	Pirojpur	Chapai Nawabganj	All areas
Education	15	12	11	13
Purchase of daily foods	32	24	28	28
Buying of land	2	6	4	4
Farm expenditure	18	24	21	21
Purchase of furniture	8	4	7	6
Purchase of agril. equipment	0	2	3	2
Family recreation	0	3	4	2
Purchase of animal feed	14	8	7	10
Savings at bank	3	7	6	5
Other purposes	8	10	10	9

3.2 Adoption of BARI Malta-1 Technology at Farm Level

The farm level adoption of BARI Malta-1 variety mainly depends on the collaborative dissemination technique used by BARI in Association with the DAE. Adoption of BARI Malta-1 is very glowing all over Bangladesh since its development in 2003 by BARI. Almost 100% farmers used BARI Malta-1 variety. Some local and exotics varieties were also used by the farmers in the study areas. The main reasons of this high adoption were availability of saplings, higher yield, and sweetness of the variety (Table 8).

Table 8. Percent of adoption of BARI Malta-1 variety at farm level

Variety	Khagrachori *(n=40)*	Pirojpur *(n=40)*	Chapai Nawabganj *(n=40)*	All areas *(n=120)*
BARI Malta-1	80 (32)	95 (38)	100 (40)	92 (110)
Other varieties	20 (8)	5 (2)	--	8 (10)

Note: Figures in the parentheses are number of respondents

Adoption of BARI Malta-1 management technologies: BARI has recommended different improved management practices likes tillage operations, time and method of seedlings, fertilizer dose, weed management, irrigation and insect-pest control. The recommended number of saplings ranged from 950 to 1050 nos. per hectare, but most of the farmers used above number of saplings except Khagrachori district. The recommended period of planting time is May to August. In that case, adoptions level was high because majority of the farmers in all areas planted their saplings within recommended period of time. It is noted that 28% farmers kept recommended plant to plant distance (4m), but 42% and 30% farmers followed below and above recommended plant to plant distance respectively. The highest percentage (56%) of farmers in all areas followed the recommended depth (75cm) of pit. Half of the respondent farmers irrigated their garden on regular basis, but in Khagrachori district 30% famers irrigated their garden. The highest percentage (75%) of farmers in all areas followed the recommended number of weeding (2 times) and 65% farmers used pesticides in their gardens (Table 9).

The recommended fertilizer doses varied according to the age of malta gardens. The use of manures and fertilizers by sample farmers varied from location to location (Table 10). Table shows that famers often do not follow recommendation for applying manure and fertilizers. Adoption status of cow dung applied in different year's garden was low since majority of the famers applied below the recommended doses. Urea applied in different years of garden was also below the recommended doses per tree. Adoption status of TSP applied in different years garden was medium, majority of the famers applied below the recommended doses. Almost all the respondent farmers applied urea, TSP, MoP, zinc oxide and boron in lower quantity compared to recommended doses in different years of garden. However, the levels of adoption of using manure and fertilizers were found to be low as they did not use recommended dose.

Table 9. Percent of adoption of crop management technologies used in malta cultivation

Particular	Khagrachori *(n=40)*	Pirojpur *(n=40)*	Chapai Nawbganj *(n=40)*	All areas *(n=120)*	Adoption level
Saplings (No./ha)					
Recommended (950-1050)	25 (10)	20 (8)	18 (7)	21 (25)	Low
Below recommendation	75 (30)	10 (4)	8 (3)	31 (37)	
Above recommendation	-	70 (28)	75 (30)	49 (58)	
Time of planting					
Recommended (May-August)	85 (34)	95 (38)	90 (36)	90 (108)	High
Non-recommended period	15 (6)	5 (2)	10 (4)	10 (12)	
Plant to plant distance					
Recommended **(4m)**	23 (9)	33 (13)	30 (12)	28 (34)	Low
Below recommendation	-	60 (24)	65 (26)	42 (50)	
Above recommendation	78 (31)	8 (3)	5 (2)	30 (36)	
Deepness of pit					
Recommended **(75cm)**	48 (19)	63 (25)	58 (23)	56 (67)	Medium
Below recommendation	35 (14)	28 (11)	13 (5)	25 (30)	
Above recommendation	18 (7)	10 (4)	30 (12)	20 (23)	
No. of irrigation					
Regular irrigation	35 (14)	70 (28)	45 (18)	50 (60)	Medium
Not regular irrigation	65 (26)	30 (12)	55 (22)	50 (60)	
No. of weeding					
Recommended (2 times)	70 (28)	78 (31)	80 (32)	75 (91)	High
Below recommendation	20 (8)	10 (4)	10 (4)	13 (16)	
Above recommendation	10 (4)	13 (5)	10 (4)	11 (13)	
Non-users					
Insect-pest control					
Do not used pesticide	58 (23)	28 (11)	20 (8)	35 (42)	
Used pesticide	43 (17)	73 (29)	80 (32)	65 (78)	
Pruning					
Regular pruning	60 (24)	73 (29)	68 (27)	67 (80)	
Never pruning	40 (16)	28 (11)	33 (13)	33 (40)	

Note: Figures in the parentheses are number of respondent farmers.

Table 10. Percent of farmers used manures and fertilizers in different ages of malta gardens

Particular	Age of the garden (year)					Adoption level
	1-2 (*n=24)*	3-4 (*n=24)*	5-7 (*n=24)*	8-10 (*n=24)*	10 & above (*n=24)*	
Cowdung (kg/tree)	10-12	12-15	15-18	18-20	20-25	
*Recommended	45.83 (11)	25.00 (6)	16.67 (4)	20.83 (5)	25.00 (6)	Low
Below recommendation	25.00 (6)	58.33 (14)	54.17(13)	70.83 (17)	66.67 (16)	
Above recommendation	8.33 (2)	-	-	-	-	
Not applied	20.83 (5)	16.67 (4)	25.00 (6)	8.33 (2)	8.33 (2)	
Urea (gm/tree)	250	400	500	650	750	
*Recommended	16.67 (4)	25.00 (6)	20.83 (50)	25.00 (6)	33.33 (8)	Low
Below recommendation	41.67 (1)	33.33 (8)	58.33 (14)	58.33 (14)	41.67 (10)	
Above recommendation	16.67 (4)	29.17 (7)	4.16 (1)	-	-	
Not applied	25.00 (6)	12.50 (3)	16.67 (4)	16.67 (4)	25.00 (6)	
TSP (gm/ha)	150	200	300	400	500	
*Recommended	54.17 (13)	62.50 (15)	33.33 (8)	29.17 (7)	45.83 (11)	Medium
Below recommendation	12.50 (3)	16.67 (4)	29.17 (7)	33.33 (8)	20.83 (5)	
Above recommendation	29.17 (7)	12.50 (3)	16.17 (4)	12.50 (3)	8.33 (2)	
Not applied	16.67 (4)	20.83 (5)	16.67 (4)	25.00 (6)	25.00 (6)	
MoP (kg/ha)	150	200	250	300	450	
*Recommended	12.50 (3)	16.67 (4)	25.00 (6)	20.83 (5)	20.83 (5)	Low
Below recommendation	--	4.17 (1)	12.50 (3)	16.67 (4)	12.50 (3)	
Above recommendation	50.00 (12)	33.33 (8)	33.33 (80)	29.17 (7)	25.00 (6)	

Particular	Age of the garden (year)					Adoption level
	1-2 (*n*=24)	3-4 (*n*=24)	5-7 (*n*=24)	8-10 (*n*=24)	10 & above (*n*=24)	
Not applied	37.50 (9)	29.17 (7)	29.17 (7)	33.33 (8)	25.00 (6)	
Zinc(kg/ha)	10	15	20	25	30	
*Recommended	25.00 (6)	20.83 (5)	29.17 (7)	25.00 (6)	16.67 (4)	Low
Below recommendation	33.33 (8)	37.50 (9)	25.00 (6)	25.00 (6)	33.33 (8)	
Above recommendation	16.67(4)	25.00 (6)	29.17 (7)	29.17 (7)	33.33 (8)	
Not applied	25.00 (6)	16.67 (4)	20.83 (5)	25.00 (6)	16.67 (4)	
Boron (kg/ha)	5	8	10	12	15	
*Recommended	33.33 (8)	25.00 (6)	37.50 (9)	37.50 (9)	33.33 (8)	Low
Below recommendation	25.00 (6)	33.33 (8)	12.50 (3)	16.67 (4)	12.50 (3)	
Above recommendation	29.17 (7)	20.83 (5)	25.00 (6)	20.83 (5)	45.83 (11)	
Not applied	16.67 (4)	20.83 (5)	25.00 (6)	25.00 (6)	12.50 (3)	

Note: Figures in the parentheses are No. of respondent farmers

*Recommended dose of fertilizers (FRG, 2005)

3.3 Determinates of Adoption of BARI Malta-1

The adoption of BARI Malta-1 at farm level were influenced by farmer's age, education, family labour, experience, training, farm size, influence of SAAO, and extension contact. The coefficients of farmer's education, training, farm size, availability of suitable land, availability of quality saplings, influence of SAAO, and extension contact had positive and significant influence on the adoption of BARI Malta-1 in the study areas. Marginal effects of different variables indicate that if these factors are increased 100% the probability of adopting BARI Malta-1 would be increased by 4.0%, 12.4%, 23.9%, 5.3%, 1.5%, 8.6%, 9.6% and 1.2% respectively (Table 12)

Table 11. Maximum likelihood estimates of variable determining adoption of BARI Malta-1 variety among respondent farmers

Explanatory variable	Coefficient	Standard Error	Z-statistic	Probability p>z
Constant	-11.2893***	1.9823	-7.08	0.000
Farmers' age (year)	0.0258	0.0235	2.64	0.003
Education (year of schooling)	0.10498 **	0.0062	1.47	0.136
Training on malta (No. of life time)	0.18925 **	0.0560	1.89	0.016
Farm size (decimal)	0.12652 **	0.1256	2.36	0.036
Family labour (No./year)	0.45784**	0.0654	1.84	0.012
Availability of suitable land (Scale,0-4;0=not available 4= plenty)	0.21354	0.0456	2.38	0.006
Availability of quality saplings (Scale,0-4;0=not available 4= plenty)	1.49253 ***	0.1352	4.36	0.038
Influence of neighbor (score) (Scale,0-4;0=not influence 4= high influence)	0.08920	0.0254	3.12	0.632
Influence of SAAO (score) (Scale,0-4;0=not influence 4= high influence)	0.39320**	0.0638	4.23	0.002
Extension contact (score) (Scale,0-4;0=no contact 4=regular contact)	0.02935**	0.0937	2.65	0.005

Table 12. Marginal effect of the variables determining adoption of BARI Malta-1 variety among respondent farmers

Explanatory variable	dy/dx	Std. Error	Z-statistic	Probability
Farmers' age (year)	0.00004	0.0235	2.34	0.009
Education (year of schooling)	0.04003**	0.0062	1.29	0.141
Training on malta (No. of life time)	0.12426**	0.0560	1.67	0.021
Farm size (decimal)	0.23892**	0.1256	2.89	0.034
Family labour (No./year)	0.05325**	0.0654	1.78	0.017
Availability of suitable land (score)	0.01532	0.0456	2.37	0.007
Availability of quality saplings (score)	0.08624***	0.1352	3.98	0.045
Influence of neighbor (score)	0.00364	0.0254	2.89	0.664
Influence of SAAO (score)	0.09604**	0.0638	4.47	0.009
Extension contact (score)	0.01243**	0.0937	2.62	0.008

Note: '**' and '***' indicate 5% and 1% level of significance respectively

3.4 Profitability of BARI Malta-1 Cultivation

Cost and return of BARI Malta-1 production: Planting materials, land preparation, input cost (FYM, fertilizers, plant growth regulators, plant protection chemicals etc.), labour cost, power cost, harvesting, packing and transportation charges were the main cost components for BARI Malta-1 cultivation. The rental value of land was treated as fixed cost and interest on operating capital was also considered for the estimation of cultivation cost. Land development and saplings costs were involved only for the first year.

The highest cost was estimated at Tk. 7,02,650/ha for BARI Malta-1 cultivation was found in the 1st year garden and the lowest cost was Tk.3,94,315/ha in the 2nd year garden. Among cost items, human labour cost was the highest (Tk.4,50,000/ha.) for first year garden. Average wage rate in the study areas was Tk. 300/days. Total variable cost was the highest (Tk. 6,02,090/ha) in the 1st year garden and the lowest (Tk. 3,16,594/ha) in the 2nd year garden. The rental value of BARI Malta-1 garden was Tk. 52,393/ha. Interest on operating capital was calculated at 8% interest rate (Table 13).

Table 13. Per hectare cost of malta cultivation in the study areas

Items	Period of cultivation (year)					
	1st	2nd	3rd	4th	5-10th	11-15th
Human labour	450000	235000	279000	297400	309500	309500
Saplings	80000	-	-	-	-	-
Cow dung	12000	8300	16500	18586	19457	24000
Urea	3650	6823	6478	7036	7231	17690
TSP	5320	5783	8560	10500	11500	19800
MP	4500	4832	7456	9864	10035	12500
Zinc	1560	2320	2450	2450	2458	3560
Boric acid	500	700	900	1350	1452	2431
Insecticides	5000	12450	12360	9548	15483	18750
Pesticides	12560	12650	13500	14560	18230	23450
Irrigation	15000	14236	14560	12540	12550	15600
Bamboo	12000	13500	13500	13500	13500	18902
Total variable cost (TVC)	602090	316594	375264	397334	421396	466183
Interest on opt. capital	48167	25328	30021	31787	33712	37295
Rental value of land	52393	52393	52393	52393	52393	52393
Total fixed cost (TFC)	100560	77721	82414	84180	86105	89688
Total cost (TVC+TFC)	702650	394315	457678	481514	507501	555871

Source: Authors' calculation based on field survey, 2018.

The return from BARI Malta-1 cultivation in different years is presented in Table 14. After two years, saplings starts producing fruits and continue up to 10-15th years. Price varied based on quality of BARI Malta-1. In the last year, farmers got an average price of Tk.80 per kg. The highest yield was found to be 19.6 t/ha at the 5-10th year garden followed by 18.00 t/ha at above 10th year old garden, and the lowest yield was 10 t/ha at the 3rd year garden. The highest gross return was estimated at Tk. 15,68,000 at the 5-10th years garden and the lowest return was Tk. 8,28,160 at the 3rd year garden. The highest gross margin was found to be Tk. 11,46,604/ha at the 5-10th year garden and the lowest Tk. 4,52,896/ha in the 3rd year garden. Similarly, the highest net return was found to be Tk. 10,60,499/ha at the 5-10th year garden and the lowest return was Tk. 3,70,481 in the 3rd year garden. Net return was negative in the 1st and 2nd year garden because production was zero.

Returns to investment of BARI Malta-1 cultivation: The profitability of malta production was also measured by estimating the benefit-cost ratio (BCR), net present value (NPV), and internal rate of return (IRR) of the investment on establishing malta orchard. The BCR of the investment was found to be 1.89 at 12% discount rate which is greater than unity and acceptable. Again, the estimated NPV was Tk. 27,06,658 per hectare which indicates that the investment on BARI Malta-1 cultivation was highly profitable. The IRR was found to be 50% which is highly acceptable because it is much higher than the opportunity cost of capital (Table 14). The above estimates (BCR, NPV & IRR) were much higher than the estimates generated for mandarin cultivation (Gangawar and Singh, 1998) and Kinnow mandarin cultivation (Gangawar et al., 2005) in India.

4. Problems of Malta Cultivation

Table 15 revealed that the highest 78% farmers opined that green color of BARI Malta-1 is the main constraints to adoption but situation is changing rapidly. About 77% farmers claimed that high saplings price and the scarcity of saplings of BARI Malta-1 in all study areas. As a result farmers cannot establish their garden. Nearly 56% farmers have not sufficient knowledge of technical aspects. Lack of suitable land, lack of marketing facilities, problem of insect/pest infestation and some others problems faced by farmers in the study areas.

Table 14. Profitability of malta cultivation in the study areas

Items	Period of cultivation (year)					
	1st	2nd	3rd	4th	5-10th	11-15th
Total cost	702650	394315	457678	481514	507501	555871
Variable cost	602090	316594	375264	397334	421396	466183
Fixed cost	52393	52393	52393	52393	52393	52393
Yield (kg/ha)	0	0	10352	13560	19600	18000
Unit price (Tk./kg)	80	80	80	80	80	80
Gross return (Tk./ha)	0	0	828160	1084800	1568000	1440000
Gross margin (Tk./ha)	-602090	-316594	452896	687466	1146604	973817
Net return (Tk./ha)	-702650	-394314	370481	603286	1060499	884129
BCR	1.89					
NPV	Tk. 27,06,658					
IRR	50%					

Table 15. Problems of BARI Malta-1 cultivation in the study areas

Problems	Farmer's responses (%)			
	Khagrachori	Pirojpur	Chapai Nawabganj	All area
Lack of suitable land	16	26	21	21
Scarcity of saplings	32	41	48	40
Higher price of sapling	72	76	83	77
Colour not attractive	84	72	79	78
Lack of technical knowledge	63	46	58	56
Less tasty	12	14	11	12
Insect-pest infestation	16	8	7	10
Lack of marketing facilities	38	32	16	29
Others	9	10	14	11

Facilities needed by the farmers: The availability of quality saplings at local level is the primary need of farmers to expand BARI Malta-1 production. Eighteen percent farmers mentioned that training on BARI Malta-1 cultivation is essential for improve production practice. About 14% of farmers demanded suitable land to cultivate BARI Malta-1. Input price of BARI Malta-1 cultivation should be reasonable as a new crop to expand farmer's field. They also demanded yellow malta varieties (6%), credit facility with low interest rate (8%), and ensuring fair price of their produces (Table 16).

Table 16. Facilities needed to increase BARI Malta-1 cultivation in different locations

Type of facility	Farmer's response (%)			
	Khagrachori	Pirojpur	Chapai Nawabganj	All area
Availability of quality saplings	28	26	31	28
Hands-on training on malta cultivation	14	18	20	18
Availability of suitable land	7	20	16	14
Ensuring low price of inputs	20	6	8	12
Credit facility with low interest	6	10	5	8
Yellow color malta varieties	8	5	4	6
Ensuring fair price of produces	7	6	6	6

5. Conclusions and Recommendations

Most of the farmers adopt BARI Malta-1 variety in their gardens. Adoption status of management technology is low in most of the cases. Farmers apply different doses of manures and fertilizers according to plant age, but it is below the recommended doses in almost all the study areas. The cost of human labour, saplings, fertilizers, and hiring of land are the major cost items of BARI Malta-1 cultivation. The benefit cost ratio, net present value and internal rate of return indicate that farmers are benefited from BARI Malta-1 cultivation in both hill regions and plain lands. Although BARI Malta-1 is a profitable crop, respondent farmers face various problems during its cultivation.

Based on the findings of the study, the following recommendations are suggested for expanding the cultivation of BARI Malta-1 throughout the country.

- The saplings of BARI Malta-1 variety should be made available to the other parts of the country through DAE, BADC and nursery owners to produce sufficient BARI Malta-1 saplings and supply to the farmers at reasonable price.
- Regular training program should be arranged for the farmers to enhance their knowledge about improved cultivation practices.
- Present green malta variety needs publicity through mass media for its higher popularity.
- The scientists should develop yellow colored malta variety.
- Respective departments may take immediate steps to control insect-pest infestation.
- Government should ensure credit facilities with minimum interest for the farmers for expanding BARI Malta-1 cultivation.

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