International Research Journal of Biological Sciences ISSN 2278-3202
Vol. **9(4),** 50-58, November **(2020)** *Int. Res. J. Biological Sci.*

Potassium-based fertilizer potentially reduces the incidence of sucking insects on okra and increases marketable yield

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Available online at: www.isca.in, www.isca.me
Received 25th June 2020, revised 4th October 2020, accepted 7th November 2020

Abstract

Plant nutrition has a substantial role on the susceptibility of plants to sucking insect pests. Hemipteran insects are very much sensitive to plant nutritional profiles. Higher than recommended level of P and K-based fertilizers would be the potential alternate of conventional insecticides for managing sucking insects in field condition. Therefore, in the present study, 10-30% higher amount of N, P and K-based fertilizers in addition with recommended doses were evaluated on the pest density of sucking insects like jassids, whiteflies and aphids on okra at different time of the study period. After given each specific treatment, data were recorded on number of sucking insects per leaf, number of curled leaves per plant and uninfested yield of okra. According to the reuslts, 30% extra application of K-based fertilizers remarkably reduced pest population density, curled leaf formation and increased yield compared to control (recommended doses of K) that was followed by 20% extra K. Application of 10% extra K was found less effective compared to 20 or 30% K. In case of phosphorus fertilizer, only 30% extra P-based fertilizer in addition with recommended doses has provided good results in reducing population incidence but 10 and 20% extra application was found less effective. 30% extra application of N-based fertilizer in addition with recommended doses strongly increased population density and decreased pod yield compared to control or 10 and 20% extra N. Benefit-cost ratio analysis showed that the highest benefit or return was found when okra plants were treated with 30% extra K-based fertilizer that was followed by 30% extra P-based fertilizer. The lowest return was found from 30% extra N-based fertilizer treated plots. Hence, application of 30% extra K-based fertilizers in addition with recommended N-P-K doses would be the potential alternate of conventional chemical insecticides in managing sucking insects like jassids, whiteflies, aphids etc. in field condition.

Keywords: Sucking insects, fertilizers, population incidence, marketable yield, okra.

Introduction

Vegetable production in Bangladesh is increasing day by day due to the favourable climatic condition, good soil fertility and effective pest management practices. In summer season, various types of vegetables are found in the market but among them okra or vendhi (*Abelmoschus esculentus*) is an important summer vegetable in Bangladesh as well as in Indian sub-continent. Green okra pods are highly nutritious as it contain vitamin, calcium, potassium, minerals etc[1-5]. Okra plays an important role in vegetable market when other vegetables are not available or less in market. The production of okra in Bangladesh is severely affected by different limiting factors like insect pest infestations and disease incidence. The most important culprit for okra production in Bangladesh is the infestation of different insects[6]. Okra is highly susceptible to different sucking insects like whitefly (*Bemisia tabaci*), jassid (*Amrasca devastans*), aphid (*Aphis gossypii*), thrips (*Thrips tabaci*), mealy bug, shoot and fruit borer (*Earias vittella*) etc[7]. Among them, jassid, whitefly and aphid are collectively known as "sucker complex" or "sucking insect complex". These insect pests are highly responsible to create different problems both directly and indirectly.

Sucking insects directly suck the cell sap from the ventral surface of the leaf through their stylets and indirectly involved in transmission of yellow vein mosaic virus. These sucking insects are also responsible to introduce chemical toxins inside the leaf tissues. Due to direct and indirect effect, infested leaves becomes yellowish, curl, dry up and finally drop down[8-10]. It is fact that most of the farmers are exclusively rely on different broad-spectrum chemical insecticides for controlling sucking insects. Indiscriminate and injudicious application of chemical insecticides has developed various burning problems like insecticide resistance, secondary pest outbreak, destruction of bio-control agents, high residues in human body etc.[11-12].

Therefore, various alternate methods are searching to control sucking insects in field condition and one of the promising method could be the application of higher doses of phosphorous and potassium based fertilizers in addition with recommended doses. There has a constructive relationship between macro-nutrients like N-P-K and insect infestation[13]. There has a positive relationship between the amount of nitrogen in cell sap and severity of infestation level[14]. High amount of nitrogen potentially increase the cell sap in cell and thereby increase food consumption, survival, growth, reproduction and population density. As a result, severe outbreak of sucking insects like jassids, aphids, whitefly, thrips etc. occurs within the short time[15-20]. On the other hand, Phosphorus (P) is another important nutrient for plant's growth and development and this central molecule of phosphate plays an important role in various biochemical processes like metabolism of nucleotides, coenzymes and phospholipids[21].

It has been reported that phosphorous strongly affect survivorship, fecundity, body size, oviposition preference, growth rate and population density of sucking insect pests[22,23]. However, this limitation of phosphorus can impose severe consequences for cellular function and ultimately the growth rate of sucking insects[24]. Potassium is an key component of plant nutrition which significantly influences crop growth as well as infestations of some sucking insects. The high amount of potassium can increases the metabolism of secondary compounds, reduce carbohydrate accumulation, elimination of some amino acids, increase the silica content in leaves and plant that protect plants from damage of insect-pests[25,26].

Therefore, the present experiment was conducted to evaluate the performance of extra amount of N-P-K-based fertilizers in addition with recommended doses in reducing incidence of sucking insects, increases of uninfected or marketable yield (t/ha) as well as benefit or return.

Materials and methods

Soil of the experimental field: All the field experiments were conducted at the Bangladesh Agricultural University research farm (24^{o}54" N latitude, 90^{o}50"E longitude at an altitude of 18m above ordnance datum). The mean annual temperature, rainfall and relative humidity are 25°C, 200mm and 79.8%, respectively (based on the last 10 years of data measured in the local weather yard). The soil of the field experiment area was under Old Brahmaputra Alluvial Tract under the Agro Ecological Zone 9 (UNDP and FAO, 1988) with non-calcareous dark grey floodplain soil. Soil contains 10, 80 and 10% sand, silt and clay respectively with the bulk density 1.3gcm^{-3}, total pore volume (TPV) of 50%, and pH of 6.7 at 0-15cm depth. Baseline SOC, TN, P and K contents at 0-15cm depth were 0.9%, 0.08%, 4 ppm and 25ppm respectively (as measured in February 2019)[27,28].

Preparation of experimental field: The whole experimental field was well ploughed, cleaned properly and kept for sun dried for 2 weeks. After that 30 plots were prepared with the size of 4 m^2 each to allocate the selected treatments. The experiment was laid out in a randomized complete block design (RCBD) with ten treatments and three replications for each treatment. Cow dung and other chemical fertilizers were applied as recommended doses for okra plant at the rate of 15 tons cow dung and 90, 20, 26kg of N_2, P and K respectively per hectare. The recommended dose was finely adjusted with soil N-P-K level. The N-P-K was applied in the form of urea, triple super phosphate (TSP) and muriate of potash (MP) respectively. The full doses of cow dung, TSP, MP and 1/4th dose of urea were applied as basal dose during land preparation. The rest of the urea was applied as top dressing in three installment at 20 days interval. Moreover, 10, 20 and 30% extra amount of N-P-K was applied in addition with recommended doses following the same application methods (Table-1). Once prepared the experimental plots, okra seeds were sown as 2-3 seeds per pit.

Table-1: Treatment specifications.

Treatment	Fertilizer doses
T_1	Recommended NPK + 10% extra N_2
T_2	Recommended NPK + 20% extra N_2
T_3	Recommended NPK + 30% extra N_2
T_4	Recommended NPK + 10% extra P
T_5	Recommended NPK + 20% extra P
T_6	Recommended NPK + 30% extra P
T_7	Recommended NPK + 10% extra K
T_8	Recommended NPK + 20% extra K
T_9	Recommended NPK + 30% extra K
T_{10}	Untreated control

Cultural operations and data collection: All cultural operations were provided timely. No control measures were taken using insecticides or others. Data were collected at 10 days interval on number of sucking insects (e.g. jassids, whitefly, aphids) per leaf, number of curled leaf per plant and marketable yield of pods (t/ha). To estimate the mean number of sucking insects per leaf, nine plants were randomly selected from three plots (3 plants/plot) and tagged with marker for counting accurately. Then, three leaves were randomly selected from each of the plant and insect populations were counted by visual searches.

Finally, a mean value was found out from nine plants (27 leaves) and expressed as mean number of insects/leaf. For estimating the mean number of curled leaves, nine plants were randomly selected from three plots and finally mean value was calculated as number of curled leaves/plant. Okra fruits were harvested from the experimental plots at 3 days interval. After harvest, infested and healthy fruits were kept separately and then weight of healthy/marketable fruits was recorded carefully and final yield was expressed in ton per hectare.

Benefit-cost ratio: At first, common cost was calculated due to the use of cow dung, chemical fertilizers, ploughing, irrigation, seeds, labors etc. After that additional cost was found out for each of the treatment due to the application of extra amount of N-P-K fertilizers. Then total cost was calculated by adding common cost and additional costs. Gross return was obtained by multiplying the yield of okra per hectare by the selling price per kg of okra. Net return was derived by subtracting the gross return from total cost. Finally BCR was calculated by using the following formula:

$$\text{Benefit-cost ratio} = \frac{\text{Net return}}{\text{Total costs}}$$

Statistical analysis: The collected data on various parameters were statistically analyzed by MSTATC package program and done analysis of variance (ANOVA). The significance of difference between the pairs of treatment mean was calculated by the Duncan's Multiple Range Test (DMRT) and Least Significant Difference (LSD) when necessary.

Results and discussion

Incidence of sucking insect pests treated with NPK-based fertilizers: The incidence or population density of jassid, whitefly and aphids following treated with NPK-based fertilizers has been shown in Table-2,4. In this experiment, okra seeds were sown on mid of the February. Jassid infestations were started in the last week of March with an average of 2-3/leaf that was remarkably increased to 7-8 times higher, then gradually decreased over time and reached to the lowest level in June. Considering all the treatments, maximum infestation was found when okra plants were treated with 30% extra N-based fertilizer in addition with recommended doses throughout the study period. For example, 39.33 jassids per leaf were found in the mid of April from 30% extra N-based fertilizer treated plot that was significantly differed by 20% (26.33) and 10% (27.17) extra N-based fertilizer. In case of control (recommended dose) condition, 25.92 jassids/leaf were found and that was insignificantly different with 20 and 10% extra N-based fertilizers (Table-2).

Appilcation of 30% extra P-based fertilizers in addition with recommended doses had significant effect on the reduction of jassid populations per leaf in comparison with that in the untreated control as well as 20 and 10% extra P-based fertilizer (Table-2, $P<0.05$). An insignificant effect was found between control and 10 and 20% extra P application regarding jassids incidence. The most striking result was found from 30% extra K-based fertilizer treated plots. For example, 13.12 jassids per leaf was found when okra plants were treated with 30% extra K in the mid of April that was significantly differed by rest of the two doses of K as well as other treatments. It was also found that 10% extra K-based fertilizer had no significant effect on the reduction of jassid populations compared to untreated control. Such type of potential effect from the application extra 30%K in addition with recommended doses was consistently found throughout the study period (Table-2).

Like as jassids, similar data collection procedure was followed for whitefly. Unlike jassid, whitefly infestation was started more or less 2 weeks later than jassid infestation i.e. whitefly infestation was initiated on 2nd week of April and reached to the peak level 10 days later and decreased quickly. This trend was continued up to 2nd week of June (Table-3). It was observed that the number of whitefly per leaf was comparatively lower than that of jassids throughout the study period. 2-3 whiteflies per leaf were counted in the mid of April that was peaked 10 days later and then declined gradually. Like as jassids, maximum infestation of whitefly was found in the month of April that potentially declined in May and June. Maximum incidence was found when okra plants were treated with 30% extra N-based fertilizer and the lowest was found from 30% extra K and P-based fertilizer treated plots. Similar trend was found in case of aphid infestation but population densities were found very less compared to jassids and whiteflies. Like as jassid and whitefly incidence, 30% extra nitrogen along with recommended doses significantly ($P<0.05$) increased aphid populations while 30% extra K application significantly reduced the populations ($P<0.05$, Table-4). Moreover, inconsistent effect was found on the incidence of aphids when okra plants were treated with extra amount of phosphorus along with recommended N-P-K based fertilizers.

Curled leaf formation: Curled leaf formation following treated with NPK-based fertilizers has been shown in Table-5. Number of curled leaves were counted at 10 days interval. Table-5 shows that the highest number of curled leaves were recorded from 30% extra N-based fertilizers treated plots ($P<0.05$) throughout the study period that was significantly followed by rest of the two doses (20 and 10% extra N) and untreated control respectively. Like as population incidence, the application of 30% extra amount of K along with recommended doses had remarkable effect on the curled leaf reduction compared to the rest of the two K doses and other treatments. Moreover, application of extra 30% P had significant effect on the reduction of curled leaves compared to control while 20 and 10% extra P application had inconsistent effect throughout the study period.

Yield (t/ha) of okra: Yield of okra (t ha^{-1}) following treated with recommended doses and extra amount of N-P-K based fertilizers has been shown in Figure-1 ($P<0.05$). Edible okra pods were harvested at 3 days interval and a cumulative yield has found out from 10 pickings. Previous incidence data clearly revealed that maximum infestation was found when okra plants were treated with 30% extra nitrogen in addition with recommended N-P-K and this high infestation was also reflected by lowest yield (5.00t ha^{-1}) ($P<0.05$). In contrast, least infestation was recorded from extra 30% K or P treated plot and that was also reflected by higher yield. The highest yield was recorded from 30% extra K-based fertilizer treated plot (6.98t ha^{-1}) that was closely followed by 30% extra P-based fertilizer (6.38 t ha^{-1}).

Table-2: Effect of different level of N-P-K based fertilizers on the incidence of jassids on okra during February to June, 2019 at BAU, Mymensingh, Bangladesh.

Treatment	Number of jassids per leaf at different observation dates									CM
	25.03.19	04.04.19	14.04.19	24.04.19	04.05.19	14.05.19	24.05.19	03.06.19	13.06.19	
T_1	2.83	15.17a	27.17a	15.56a	4.18b	4.33a	6.50a	4.83a	2.67a	9.25a
T_2	2.95	17.00a	26.33a	18.09b	4.17b	3.67b	6.00a	5.50a	2.67a	9.60a
T_3	3.17	23.00b	39.33b	27.50c	6.78c	5.67c	8.90b	6.78b	3.12b	13.81b
T_4	2.87	13.45a	25.00a	14.50a	4.50b	5.11c	7.11c	4.67a	3.00a	8.91a
T_5	2.77	12.56ac	23.33a	13.34a	3.83b	4.90c	7.17c	5.00a	4.17c	8.56a
T_6	2.50	11.56c	18.50c	11.21d	3.00d	4.00b	6.00a	4.56a	3.00a	7.09c
T_7	3.00	15.11a	23.45a	15.30a	5.83a	4.00b	5.67a	5.00a	4.50c	8.87a
T_8	2.56	12.22c	20.78d	12.50d	5.00a	4.45b	5.00d	4.12b	3.45c	7.80c
T_9	2.45	8.67d	13.12e	9.00e	2.34e	2.50d	4.10e	3.00c	1.45d	5.18d
T_{10}	2.79	14.28a	25.92a	14.40a	5.33a	4.08a	6.25a	4.83a	2.08a	8.88a
LSD $_{0.05}$	0.88	0.95	0.56	0.62	0.50	0.55	0.77	0.80	0.68	0.77

Table-2: Effect of different level of N-P-K based fertilizers on the incidence of jassids on okra during February to June, 2019 at BAU, Mymensingh, Bangladesh.

Treatment	Number of jassids per leaf at different observation dates									CM
	25.03.19	04.04.19	14.04.19	24.04.19	04.05.19	14.05.19	24.05.19	03.06.19	13.06.19	
T_1	2.83	15.17a	27.17a	15.56a	4.18b	4.33a	6.50a	4.83a	2.67a	9.25a
T_2	2.95	17.00a	26.33a	18.09b	4.17b	3.67b	6.00a	5.50a	2.67a	9.60a
T_3	3.17	23.00b	39.33b	27.50c	6.78c	5.67c	8.90b	6.78b	3.12b	13.81b
T_4	2.87	13.45a	25.00a	14.50a	4.50b	5.11c	7.11c	4.67a	3.00a	8.91a
T_5	2.77	12.56ac	23.33a	13.34a	3.83b	4.90c	7.17c	5.00a	4.17c	8.56a
T_6	2.50	11.56c	18.50c	11.21d	3.00d	4.00b	6.00a	4.56a	3.00a	7.09c
T_7	3.00	15.11a	23.45a	15.30a	5.83a	4.00b	5.67a	5.00a	4.50c	8.87a
T_8	2.56	12.22c	20.78d	12.50d	5.00a	4.45b	5.00d	4.12b	3.45c	7.80c
T_9	2.45	8.67d	13.12e	9.00e	2.34e	2.50d	4.10e	3.00c	1.45d	5.18d
T_{10}	2.79	14.28a	25.92a	14.40a	5.33a	4.08a	6.25a	4.83a	2.08a	8.88a
LSD $_{0.05}$	0.88	0.95	0.56	0.62	0.50	0.55	0.77	0.80	0.68	0.77

Values within a column followed by the same letter are not significantly differentl at 5% level of probability. CM: Cumulative mean. [T_1: Rec. NPK + 10% extra N, T_2: Rec. NPK + 20% extra N, T_3: Rec. NPK + 30% extra N,T_4:Rec. NPK + 10% extra P, T_5: Rec. NPK + 20% extra P, T_6: Rec. NPK + 30% extra P, T_7: Rec. NPK + 10% extra K, T_8: Rec. NPK + 20% extra K, T_9: Rec. NPK +30% extra K, T_{10}: Control or recommended level of NPK].

Table-3: Effect of different level of N-P-K based fertilizers on the incidence of whitefly on okra during February to June, 2019 at BAU, Mymensingh, Bangladesh.

Treatment	Number of whitefly per leaf at different observation dates									CM
	25.03.19	04.04.19	14.04.19	24.04.19	04.05.19	14.05.19	24.05.19	03.06.19	13.06.19	
T_1	0.00	0.00	3.33a	4.83a	2.99a	1.22a	1.00a	1.17a	1.00a	1.73a
T_2	0.00	0.00	5.00b	5.78b	3.33a	1.00a	1.00a	1.17a	1.17a	2.05a
T_3	0.10	0.11	7.83c	9.17c	6.00b	2.50b	2.56b	2.00b	1.90b	3.57b
T_4	0.00	0.00	3.12a	4.00a	3.57a	1.23a	1.18a	1.33a	1.50a	1.77a
T_5	0.00	0.00	3.00a	4.34a	3.33a	1.50a	1.07a	1.33a	1.23a	1.76a
T_6	0.00	0.00	2.50a	3.78d	1.44c	1.12a	1.00a	0.88c	1.00a	1.30c
T_7	0.00	0.00	2.80a	4.22a	2.73a	1.33a	1.33a	1.17a	1.50a	1.48a
T_8	0.00	0.00	2.67a	3.00d	1.85c	1.00a	0.80c	0.77c	0.83c	1.21c
T_9	0.00	0.00	1.22d	1.12e	0.56d	0.70c	0.34d	0.50d	0.55d	0.55d
T_{10}	0.00	0.00	3.25a	4.08a	3.00a	1.31a	1.18a	1.33a	0.80a	1.66a
LSD $_{0.05}$	0.00	0.00	0.82	0.85	1.04	0.57	0.62	0.34	0.54	0.44

Values within a column followed by the same letter are not significantly differently at 5% level of probability. CM: Cumulative mean. [T_1: Rec. NPK + 10% extra N, T_2: Rec. NPK + 20% extra N, T_3: Rec. NPK + 30% extra N, T_4:Rec. NPK + 10% extra P, T_5: Rec. NPK + 20% extra P, T_6: Rec. NPK + 30% extra P, T_7: Rec. NPK + 10% extra K, T_8: Rec. NPK + 20% extra K, T_9: Rec. NPK +30% extra K, T_{10}: Control or recommended level of NPK].

Table-4: Effect of different level of N-P-K based fertilizers on the incidence of aphids on okra during February to June, 2019 at BAU, Mymensingh, Bangladesh

Treatment	Number of aphids per leaf at different observation dates									CM
	25.03.19	04.04.19	14.04.19	24.04.19	04.05.19	14.05.19	24.05.19	03.06.19	13.06.19	
T_1	0.00	0.00	0.41a	0.82a	0.90a	0.82a	0.83a	0.67b	0.20a	0.52a
T_2	0.00	0.00	1.00b	1.50b	0.95a	0.82a	0.90a	1.00a	0.17a	0.70a
T_3	0.00	0.00	2.12c	2.20c	1.56b	1.34b	1.17b	1.30c	0.20a	1.10b
T_4	0.00	0.00	0.45a	0.70a	0.90a	0.68c	0.99a	1.17a	0.11b	0.56a
T_5	0.00	0.00	0.35a	0.65a	0.81a	0.60c	0.83a	1.00a	0.11b	0.48a
T_6	0.00	0.00	0.33a	0.60a	0.70a	0.56c	0.70c	0.78d	0.00c	0.31c
T_7	0.00	0.00	0.43a	0.70a	0.79a	0.70c	1.00b	1.00a	0.17a	0.53a
T_8	0.00	0.00	0.30a	0.60a	0.60c	0.60c	0.80a	0.90a	0.10b	0.40a
T_9	0.00	0.00	0.22d	0.25d	0.30d	0.30d	0.44d	0.67e	0.10b	0.25d
T_{10}	0.00	0.00	0.42a	0.78a	0.83a	0.80a	0.92a	1.17a	0.20a	0.57a
LSD $_{0.05}$	0.00	0.00	0.22	0.32	0.22	0.27	0.42	0.30	0.22	0.34

Values within a column followed by the same letter are not significantly differently at 5% level of probability. CM: Cumulative mean. [T_1: Rec. NPK + 10% extra N, T_2: Rec. NPK + 20% extra N, T_3: Rec. NPK + 30% extra N, T_4:Rec. NPK + 10% extra P, T_5: Rec. NPK + 20% extra P, T_6: Rec. NPK + 30% extra P, T_7: Rec. NPK + 10% extra K, T_8: Rec. NPK + 20% extra K, T_9: Rec. NPK +30% extra K, T_{10}: Control or recommended level of NPK].

Table-5: Effect of different level of N-P-K based fertilizers on the number of curled leaves per okra plant during February to June, 2019 at BAU, Mymensingh, Bangladesh.

Treatment	Number of curled leaf per okra plant at different observation dates									CM
	25.03.19	04.04.19	14.04.19	24.04.19	04.05.19	14.05.19	24.05.19	03.06.19	13.06.19	
T_1	1.53	3.33a	6.20a	6.70a	7.45a	6.00a	5.83a	5.33a	4.67b	5.60a
T_2	1.63	4.00a	7.00a	7.00a	8.00a	7.40b	6.50a	6.90a	6.40c	6.09a
T_3	1.67	4.50b	8.50c	9.00b	9.23b	9.00c	8.00c	8.50c	8.00d	7.38b
T_4	1.67	3.67a	5.83a	6.00d	6.00c	6.33a	6.83b	5.17a	5.70e	5.24a
T_5	1.77	3.50a	5.80a	5.60e	5.50d	6.00a	6.57b	5.00a	5.00f	4.97a
T_6	1.67	3.11a	5.10b	5.00e	5.00d	5.50d	5.80a	4.67d	5.00f	4.38c
T_7	2.00	3.00a	5.00a	5.83d	7.00a	6.11a	6.00d	4.50d	5.50f	4.99a
T_8	2.17	2.50c	4.00d	5.00f	6.00e	5.50d	5.34a	5.00a	5.00f	4.50c
T_9	1.78	2.00d	3.50e	3.00g	3.45f	2.50e	2.50e	3.00e	3.50g	3.14d
T_{10}	1.58	3.33a	6.08a	6.50a	7.25a	6.42a	5.78a	5.17a	5.25f	5.26a
LSD $_{0.05}$	0.00	0.35	0.52	0.65	0.48	0.66	0.42	0.35	0.32	

Values within a column followed by the same letter are not significantly differently at 5% level of probability. CM: Cumulative mean. [T_1: Rec. NPK + 10% extra N, T_2: Rec. NPK + 20% extra N, T_3: Rec. NPK + 30% extra N, T_4:Rec. NPK + 10% extra P, T_5: Rec. NPK + 20% extra P, T_6: Rec. NPK + 30% extra P, T_7: Rec. NPK + 10% extra K, T_8: Rec. NPK + 20% extra K, T_9: Rec. NPK +30% extra K, T_{10}: Control or recommended level of NPK].

Table-6: Economic analysis of different treatments used for managing sucking insects on okra.

Treatments	Common costs/ha (Tk.)	Additional cost for using extra NPK/ha (Tk.)	Total costs/ha (Tk.)	Yield (t/ha)	Gross return (Tk.)	Net return (Tk.)	Benefit Cost ratio (BCR)
Rec. NPK+ 10% extra N (T_1)	75000	351	75351	5.59	167700	92349	1.22
Rec. NPK+ 20% extra N (T_2)	75000	702	75702	5.51	165300	89598	1.18
Rec. NPK +30% extra N (T_3)	75000	1053	76053	5.00	150000	73947	0.97
Rec. NPK+ 10% extra P (T_4)	75000	280	75280	5.61	168300	93020	1.23
Rec. NPK+ 20% extra P (T_5)	75000	560	75560	5.95	178500	102940	1.36
Rec. NPK +30% extra P (T_6)	75000	840	75840	6.38	191400	115560	1.52
Rec. NPK+ 10% extra K (T_7)	75000	94	75094	5.63	168900	93806	1.24
Rec. NPK+ 20% extra k (T_8)	75000	188	75188	5.86	175800	100612	1.33
Rec. NPK +30% extra K (T_9)	75000	282	75282	6.98	209400	134118	1.78
Control (Rec. NPK) (T_{10})	75000	0.00	75000	5.40	162000	87000	1.16

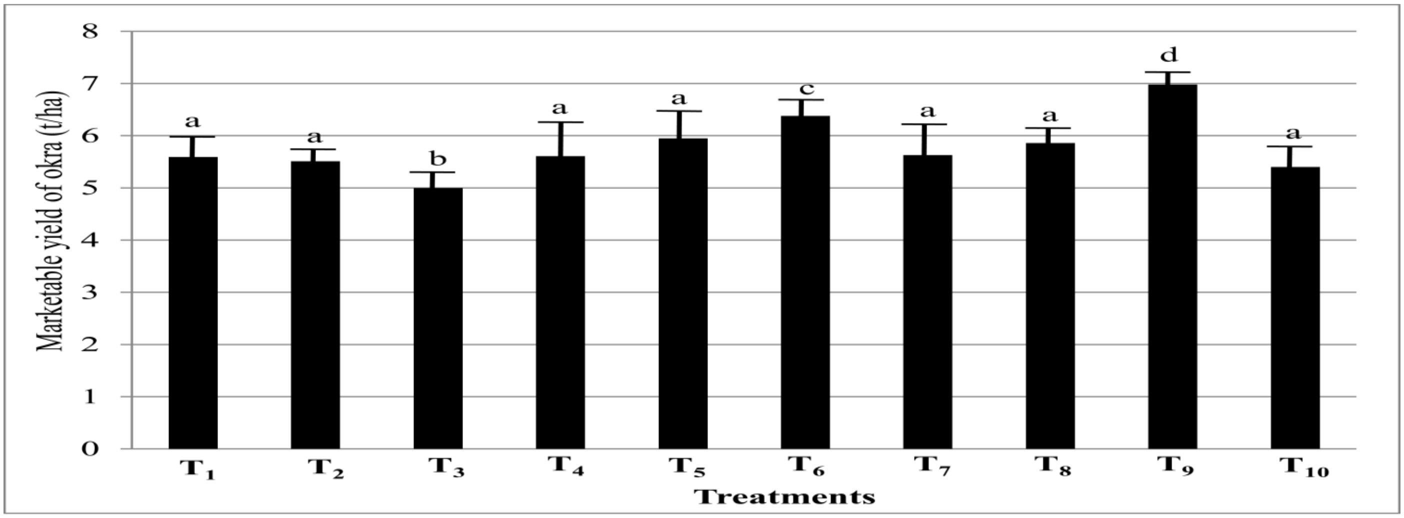

Figure-1: Effect of different levels of N-P-K based fertilizers on the marketable yield of okra (t/ha). Different letters on each bar indicates significant difference among the treatments at 5% level of probability. [T_1:Rec.NPK + 10% extra N, T_2: Rec.NPK + 20% extra N, T_3: Rec. NPK + 30% extra N, T_4:Rec. NPK + 10% extra P, T_5: Rec. NPK + 20% extra P, T_6: Rec. NPK + 30% extra P, T_7: Rec. NPK + 10% extra K, T_8: Rec. NPK + 20% extra K, T_9: Rec. NPK +30% extra K, T_{10}: Control or recommended level of NPK].

Discussion: The present study clealry elucidated that the application of 30% extra K-based fertilizers in addition with recommended doses of N-P-K potentially reduced sucking insects population and increased yield compared to other treatments. Application of 30% extra P-based fertilizers also had good effect to reduce infestation as well as increase yield. Moreover, uses of 10 and 20% extra K or P had fairly good effect to reduce infestation level but yield (t/ha) was not increased significantly compared to control or recommended doses. In contrast, the highest infestation level and the lowest yield was recorded when okra plants were treated with 30% extra N-based fertilizers. Effect of 10 or 20% extra N application was found comparable with untreated control. Furthermore, the treatment 30% extra K+ recommended doses of N-P-K was found economically effective as it resulted maximum net benefit and highest B:C ratio.

Our present study clearly showed that the highest population incidence per leaf and maximum curled leaves per plant were found when okra plants were treated with 30% extra N-based fertilizers and it resulted the lowest yield and B:C ratio. This findings raises the possibility that excess nitrogenous fertilizers might change the physiology of host plants that ultimately affects the herbivores biology, biochemistry and overall interactions. Our results are well supported by Singh and Sood who reported that excess application of N-based fertilizer has potential effect on growth and development of all the hemipteran insects[29]. It was also studied that high level of nitrogen is associated with high photosynthetic activity, high vegetative growth, dark green leaves, high cell sap, less silica content etc. and these are highly favorable for sucking insect infestations[19,30]. Another study reported that high N-fertilizers doses result in increased oviposition, abundance and survival of different species of whiteflies[31]. Our study also observed that 30% extra P-based fertilizers had profound effect in reducing infestation level and increase yield with high net benefit. Lower doses (10 and 20%) were found to be comparatively less effective in reducing infestation but yield was not changed significantly compared to control. Our results are in agreement with the findings of previous worker who reported that phosphorus molecule potentially affect survivorship, fecundity, body size, oviposition preference, growth rate and population density of several herbivores[32].

In the present study, the most striking result was observed from 30% extra K-based fertilizers treated plots. Application of this treatment has resulted the lowest pest incidence, minimum curled leaves, highest yield with maximum net benefit (1.78 B:C ratio). The role of K in mitigating crop damage due to insects has been well documented. It has been reported that high level of K along with recommended nitrogen can enhance secondary compound metabolism, reduce carbohydrate accumulation, elimination of amino acids, increase the silica content of leaves. Moreover, high potassium supply tends to harden plant structure like stronger cuticle, stronger outer wall of epidermis, stronger cell walls, increase sclerenchymatous tissues and silicification and finally thicker and harder the stem[25-26]. This hardening of plant structure is generally considered to improve mechanical resistance to feeding of insects especially sucking insects[33].

Conclusion

Application of 30% extra P-based fertilizers in addition with recommended N-P-K would be moderately effective in reducing sucking insects infestations. But the most striking result was found from 30% extra K application in addition with recommended N-P-K. Therefore, it is concluded that application of 30% extra K-based fertilizers in addition with recommended N-P-K would be the potential alternate of conventional chemical insecticides in managing sucking insects like jassids, whiteflies, aphids etc. in field condition.

Acknowledgements

This research work was financially supported by the grants from Bangladesh Agricultural University Research System (BAURES).

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