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Flower Synchrony, Growth and Yield Enhancement of Small Type Bitter Gourd (*Momordica charantia* L.) Through Plant Growth Regulators and NPK Fertilization

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Abstract: Assessment of growth regulator and NPK fertilization effects are important tools for flower stimulation and yield improvement in cucurbits. This investigation demonstrates the comparative male-female flower induction and fruit yield of small sized bitter gourd treated with NPK fertilizers and plant growth regulators. Namely, two experiments having three replicates were conducted in a Randomized Complete Block Design (RCBD) with NPK fertilization and plant growth regulators-GA_3, NAA and Ethophon application on small sized bitter gourd-genotype BG5 at the research field of the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU). In experiment 1, different doses of NPK fertilizers comprised of 10 treatments and in that of experiment 2, different levels of plant growth regulators indicated 10 treatments. The results indicated that application of different doses of NPK fertilizer and plant growth regulators significantly (≤0.05) influenced over the flower initiation and fruit setting. The application of N90-P45-K60 fertilizer along with Ethophon spraying resulted in the better yield of small sized bitter gourd.

Key words: Bitter gourd, plant growth regulator, flower synchrony, yield

INTRODUCTION

Widely cultivated and popularly used bitter gourd (*Momordica charantia* L.), a monoecious creeper is a nutritious and delicious vegetable tropical part of the world (Behera *et al*., 2011) and all over the Bangladesh. With its excellent medicinal virtues, small sized but little oval shaped and dark green cultivar usually called 'Uchjha' is more fascinated by the consumers due to its taste and high nutritional values. Additionally, the fruits, leaves and roots of *M. charantia* L. have also been used in Ayurveda for a number of diseases such as bitter stomachic, laxative and anthelmintic (Din *et al*., 2011; Hossain *et al*., 2006; Shetty *et al*., 2005).The extract of the fruit is also advocated in diseases of spleen, liver, rheumatism and gout. It is usually eaten fresh (stuffed and/or sliced) but can also be pickled for canning along with its young shoots and leaves (Behera *et al*., 2010).

'Uchjha' cultivation in Bangladesh has been increasing day by day in terms of both area and total production. However, its average yield (6-7 t ha^{-1}) is quite low compared to other countries (Huyskens *et al*., 1992; Kuang *et al*., 1997). The main reasons responsible for such low yields of 'Uchjha' in Bangladesh are use of low quality of seeds; application of imbalanced manures and fertilizers vis-à-vis fertilization induced by unsynchronized male/female flowering. Of the reasons, non-judicious application of fertilizers and asynchrony of male and female flowering are vital factors for the poor yield of 'Uchjha' in Bangladesh. So, its production increase through balanced fertilization and synchronized male and female flowering deserve to be prioritized.

Established fact is that nitrogen use efficiency for the crop yield largely ranges between 25 to 35% and seldom 50%. Further, inadequate use of other nutrient element namely P and K impede growth, affect fruit setting and reduces yield. Even the excess nitrogen accumulated in the cell may be hazardous for human health. Therefore, enhancement of the use efficiency in particular N by identifying the maximum N-assimilation pattern coupled with carbohydrate translocation and economic sink as well needs to be addressed.

Meanwhile, asynchrony of male/female flower and abortion of immature fruit are common problems in bitter gourd cultivation which consequently reduce the yield. Attempts have been made to overwhelm this problem. Application of IAA, GA and NAA increased yields in cucurbits through synchronized flowering (Basu *et al*.,

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1994; Ghosh and Basu, 1983; Tolentino and Cadiz, 2005; Hidayatullah *et al*., 2012; Akter and Rahman, 2010). On the other hand, a combination of balanced fertilizer and growth regulators induces synchronized flowering and better fruit set in bitter gourd (Ali *et al*., 1995; Samdyan *et al*., 1994). These facts suggest that there is a greater possibility of bringing synchrony in flowering leading to the expected yield with the appropriate use of fertilizer and growth regulators in 'Uchjha'. In this report, we describe the experiments conducted to investigate the male-female flowering induction, fruit setting and yield in 'Uchjha' relevant to PGR and N, P, K application.

MATERIALS AND METHODS

Experiment 1: The experiment was conducted at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) under natural conditions. The soil of the experimental site was silty clay loam in texture belonging to Salna series having a pH of 5.5, 0.054% total nitrogen and 1.38% organic matter. The small type bitter gourd 'Uchjha' (*Momordica charantia* L.) of BG5 genotype was used in current investigation. The experiment was laid out in a randomized complete block design with three replications. The following treatments were used in the experiment: T_1– control (no fertilizer applied), T_2-$N_0\,P_{45}\,K_{60}$, T_3-$N_{60}\,P_{45}\,K_{60}$, T_4-$N_{90}\,P_{45}\,K_{60}$, T_5-$N_{120}\,P_{45}\,K_{60}$, T_6-$N_{90}\,P_0\,K_{60}$, T_7-$N_{90}\,P_{30}\,K_{60}$, T_8-$N_{90}\,P_{60}\,K_{60}$, T_9-$N_{90}\,P_{45}K_0$ and T_{10}-$N_{90}\,P_{45}\,K_{80}$.

The land was opened with a tractor; ploughed and cross-ploughed with a power tiller followed by laddering to bring leveled good tilth for sowing. Four days before transplanting, necessary irrigation channels were made around the plots. The N, P and K were applied as urea, Triple Super Phosphate (TSP) and Muriate of Potash (MOP), respectively. The whole amount of TSP, MOP, Gypsum and Zinc Sulphate were applied at the final land preparation. While urea was applied in three equal splits at 15, 30 and 60 Days after Transplanting (DAT). Seeds were germinated and raised in cow dung filled polyethylene bags under nursery shade conditions, six uncontaminated and homogeneous one month old "Uchjha" seedlings with hard five leaves were transplanted at the spacing of 1×1 m.

Experiment 2: The experiment was conducted at the experimental farm of the Crop Botany Department of BSMRAU, Gazipur, Bangladesh on the same soil with the same plant material and the same methodology of land preparation, fertilizer application, designing and seedling transplanting. However, the whole experimental area was divided into three equal blocks, each representing one replication. Each block was sub-divided into 10 plots, thus the total number of unit plots was 30 and the unit plot size was 4×2.5 m with an inter block and inter plot spacing of 1 and 1 m, respectively. Ten treatments imposed for the experiment were: T_1: GA_3 20 ppm, T_2: GA_3 40 ppm, T_3: GA_3 60 ppm, T_4: NAA 50 ppm, T_5: NAA 75 ppm, T_6: NAA 100 ppm, T_7: Ethophon 100 ppm, T_8: Ethophon 150 ppm, T_9: Ethophon 200 ppm, T_{10}: control. These growth regulator combinations were applied exogenously at 21, 35 and 50 DAT, respectively with the help of hand sprayer.

Mature fruits were harvested at 3 days interval up to ageing of plants and data on yield and yield attributes were recoded encompassing the border effect. The plants were terminally harvested at 120 DAT and shoot dry matter was taken by drying the sample in an electric oven at 71°C for three days and statistical analyses were performed by Least Significant Difference (LSD) test among the treatment means after Gomez and Gomez (1984) by using MSTATC computer package.

RESULTS

Experiment 1

Growth parameters: Combined NPK fertilizers imparted significantly ($p \le 0.05$) on the enhancement of main vine and number of primary branches per plant (Table 1). The vine length increased with the increased rates of nitrogen application. Nitrogen application at the rates of 60, 90, 120 kg ha^{-1} in presence of other nutrients produced 20-35% higher vine length over control. However, vine length was not significantly influenced by the different levels of P and K applications (Table 1). These findings suggest that combinations of NPK fertilizers affect main vine and branch production in small sized bitter gourd differentially. However, the extent of main vine and branch production relationship regardless of NPK rates remained to be studied.

Fruit number and size: Table 2 shows the differential effect of NPK fertilizers on the fruit size and fruit number of bitter gourd. Generally, fruit number showed a curvilinear relationship with the increment NPK fertilizer.

Table 1: Effect of NPK doses on vine length and number of primary branches of small type bitter gourd

Treatments	Vine length (cm)	No. of primary branch
$N_0P_0K_0$	225^{d}	5.45^{e}
$N_0P_{45}K_{60}$	240^{cd}	6.42^{d}
$N_{60}P_{45}K_{60}$	275^{bcd}	10.58^{c}
$N_{90}P_{45}K_{60}$	295^{abc}	11.60^{b}
$N_{120}P_{45}K_{60}$	315^{ab}	12.58^{a}
$N_{90}P_0K_{60}$	280^{bcd}	10.57^{c}
$N_{90}P_{30}K_{60}$	320^{ab}	10.67^{c}
$N_{90}P_{60}K_{60}$	295^{abc}	11.61^{b}
$N_{90}P_{45}K_0$	265^{bcd}	10.90^{c}
$N_{90}P_{45}K_{80}$	350^{a}	11.58^{b}

Any two means having a common letter (s) do not differ at $p \le 0.05$ levels of significance

Table 2: Effect of NPK fertilizes on the fruit size, number and yield of small type bitter gourd

Treatments	Fruit size (g fruit $^{-1}$)	No. of fruit plant^{-1}	Fruit yield (t ha^{-1})
$N_0P_0K_0$	25.53^{g}	20.17^{h}	3.09^{f}
$N_0P_{45}K_{60}$	35.62^{f}	20.17^{h}	4.34^{e}
$N_{60}P_{45}K_{60}$	43.58^{d}	24.83^{f}	6.95^{c}
$N_{90}P_{45}K_{60}$	46.24^{ab}	33.08^{a}	8.35^{ab}
$N_{120}P_{45}K_{60}$	42.95^{e}	27.51^{d}	6.88^{c}
$N_{90}P_0K_{60}$	45.48^{b}	22.98^{g}	5.90^{d}
$N_{90}P_{30}K_{60}$	44.23^{c}	27.02^{e}	7.22^{c}
$N_{90}P_{60}K_{60}$	46.41^{a}	27.67^{d}	7.19^{c}
$N_{90}P_{45}K_0$	43.95^{cd}	29.6^{c}	7.97^{b}
$N_{90}P_{45}K_{80}$	43.90^{cd}	31.33^{b}	8.63^{a}

Any two means having a common letter(s) do not differ at $p \leq 0.05$ levels of significance

However, the highest number of fruit was recorded in the treatment of N90-P45-K60 followed by N90 P45 K0. Conversely the lowest number of fruits was produced in control treatment. The remaining treatments showed the intermediate status. Similar trends were also observed in case of fruit size. So, combination of NPK fertilizers had a positive effect on the fruit size enlargement and enhancement of fruit numbers.

Fruit yield: As shown in Table 2, NPK combinations exerted significant ($p \leq 0.05$) role on the fruit yield of bitter gourd. The highest fruit yield (8.63 t ha^{-1}) was recorded in the $N_{90}P_{45}K_{80}$ treatment and that of the lowest was found in the $N_0P_0K_0$ control treatment. From the Table 2, it was also revealed that different NPK combinations (T_2-T_{10}) resulted in 28.80 to 55.53%, fruit yield increase.

Generally, fruit number showed a curvilinear relationship with the increment NPK fertilizer. The highest number of fruit was recorded in the treatment of N90-P45-K60 followed by N90 P45 K0. Conversely the lowest fruits were produced in control treatment. The remaining treatments showed the intermediate status.

Experiment 2

Days to appearance of first flower: Plant growth regulator at different concentration showed a significant influence on the days to first flower. The first male flower was observed in NA 75 ppm at 31 DAT followed by GA_3-20 ppm (34 DAT). Application of GA_3 60 ppm took the minimum number of days for the appearance of first female flower (34 to 35 DAT) which was about 12 days earlier to control. Higher number of female flower was initiated by the application of Ethophon at the rate of 50 ppm. Application of GA_3 was very effective for early male and female flowering. Gedam *et al.* (1998) and Akter and Rahman (2010) found similar effect in increase the female flowers due to foliar application of different PGR in bitter gourd.

GA3 and NAA at 50 ppm produced the first male flower at 11th and 12th nodes, respectively. Whereas,

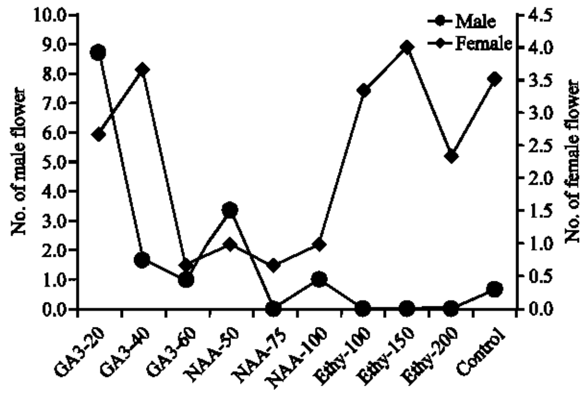

Fig. 1: Effect of plant growth regulators on the flowering pattern of small sized bitter gourd grown under field condition

NAA at 50, Ethopon at 200 ppm and GA_3 and 50 ppm produced first female flower at around 7th node. Verma *et al.* (1984) observed first female flower at lower node due to application of GA_3 (150 ppm) and MH (250 pmm) in bitter gourd thus partly supporting the present finding.

Number of male and female flowers: The total number of male and female flower was significantly influenced by the application of plant growth regulators and plant nutrient at different levels (Fig. 1). The plants sprayed with Ethophon at 150 ppm produced the highest number of female flowers and was significantly superior to all the other treatments followed by GA 40 ppm.

NAA and Ethophon also produced the lowest desirable sex ratio suppressing the male flowers (Gedam *et al.*, 1998). Similar increase in the number of female flowers due to foliar application of ethrel (Ethophon) at 200 and 400 ppm and MH at 150 and boron at 4 ppm has been reported in bitter gourd. Ethrel increased the number of pistillate flowers but also hastened the appearance of the first female flower compared to control. The effect of ethrel on the staminate flowers was the opposite i.e. it delayed the appearance of the first staminate flower and also decreased the total number of male flowers. Sreeramulu (1987) also observed the similar finding in *Luffa cylindrica*.

The ratio of male and female flower: The ratio of male and female flowers greatly determines the yield of fruit in cucurbitaceous vegetables. The application of plant growth regulators at different concentrations significantly influenced the sex ratio (Fig. 2). Application of Ethophon at 200 ppm showed the lower ratio. NAA and Ethophon produced lowest sex ratio suppressing male flower with

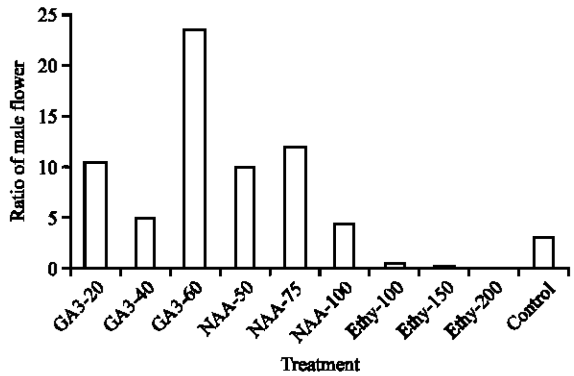

Fig. 2: Effect of plant growth regulators on the ratio of male-female flowers of small sized bitter gourd grown under field condition

Table 3: Effect of plant growth regulators on the yield attributes and yield of small sized bitter gourd grown under field condition

Treatments	Shoot dry weight (g plant^{-1})	Fruit weight (g)	No. of fruits plant^{-1}	Fruit yield (kg plant^{-1})	Fruit yield (t ha^{-1})
GA_3-20	192.6^{c}	17.14^{f}	63.23^{j}	1.12^{d}	6.71^{d}
GA3-40	183.5^{f}	16.71^{fg}	515.5^{a}	1.43^{ab}	8.64^{ab}
GA_3-60	149.4^{g}	22.75^{c}	374.2^{g}	1.44^{ab}	8.61^{ab}
NAA-50	261.3^{a}	18.77^{e}	420.8^{d}	1.32^{bc}	7.92^{bc}
NAA-75	225.0^{c}	28.59^{a}	272.6^{i}	1.29^{bc}	7.72^{bc}
NAA-100	236.0^{b}	22.87^{bc}	408.5^{e}	1.54^{a}	9.23^{a}
Ethophon-100	135.7^{b}	21.79^{d}	429.6^{c}	1.54^{a}	9.21^{a}
Ethophon-150	266.9^{a}	16.49^{g}	492.2^{b}	1.33^{bc}	7.99^{bc}
Ethophon-200	216.9^{d}	23.38^{b}	314.2^{h}	1.21^{cd}	7.23^{cd}
Control	195.3^{e}	22.72^{c}	346.0^{g}	1.31^{bc}	7.87^{bc}

In a column figures having same letter(s) do not differ at $p \leq 0.05$ levels of significant

increasing the female flowers. The increased number of female flowers in Ethophon at 200 ppm treated plants can be attributed to physiological and biochemical changes caused by the plant nutrient and plant growth regulators interaction.

Shoot dry weight: The effect of plant growth regulators was found to be highly significant on shoot weight of bitter gourd (Table 3). The highest shoot weight was produced by the application of Ethophon at the rate 150 ppm followed by NAA 50 ppm. Lower shoot weight was produced by the application of GA_3.

Fruit size (single fruit weight): Application of PGR greatly stimulated the fruit size of small sized bitter gourd (Table 3). Heaviest Fruit was produced by the application of NAA 75 ppm and the lowest was produced by the application GA_3 60 ppm. The remaining treatments showed the intermediate status. In control the average fruit size was 22.65 g fruit^{-1}.

Number of fruits per plant: The number of fruits per plant throughout the whole growth period was significantly influenced by the application of plant growth regulators. The highest number of fruits per plant was observed in GA_3 40 ppm followed by Ethophon 150 ppm conversely the lowest number of fruits was found in NAA 75 ppm. The higher number of fruits was due to higher pistillate flower which consequently produced the fruit.

Fruit yield: The effect of different levels of PGR on fruit yield of bitter gourd was highly significant (Table 3). The highest fruit yield was recorded by the application of Ethophon 100 ppm (17% more) and NAA 100 ppm, (17-18% more) which was statistically identical with GA_3 40 and GA_3 60 ppm. Conversely, control treatment produced lower fruit yield (7.87 t ha^{-1}).

DISCUSSION

The results clearly indicated that the plant growth characters like vine length, number of primary branches, leaf area and total dry matter production plant^{-1} increased significantly due to the application of different plant growth regulators and chemical fertilizers (NPK). The Ethophon increased all these characters excepting vine length while the application of GA_3 and NAA increased the vine length. Ethophon suppressed the vine growth possibly through anti-gibberellins activity and increased the number of leaf and dry matter production by increasing the number of primary braches. Similarly, the higher rates of NPK showed decreased effect in increasing all these characters.

Exogenous application of plant growth regulators in combination with balanced major fertilizers NPK has shown considerable improvement in sex expression. The application of GA_3 might have resulted in early production of staminate flowers as expression of androecy (Singh and Choudhury, 1988).

External application of GA_3 able to add the quality and quantity of endogenous gibberellins like substances within the plant also cause the stimulation of staminate flower production. In plant developmental ontogeny of bitter gourd the concentration of endogenous growth regulators are altered in shoot apical meristem and affect the formation of male and female flower (Wang *et al*., 1997). Friedlander *et al*. (1977) observed that the first staminate bud differentiation in node number 3 to 5 was accompanied by increase in ABA and GA_3 content in monoecious cucumber.

NAA at both concentration produced early male flowers in lower nodes. It might be due to increased level of endogenous auxins in plant which induced the initiation of female flowers. Ethophon 150 ppm treatment delayed the formation of first staminate flower whereas, it induced earlier formation of first pistillate flowers compared to all other treatments. The reduced level of gibberellins in plant after Ethophon treatment may be responsible for delayed appearance of staminate flowers. On the other hand, the increased level of endogenous auxin might be responsible for early induction of female flowers in this crop. The sexual differentiation is controlled by the endogenous level of auxins in regions neighboring the flowering primordia and during flowering the formation of female organs may be favored by high auxin level in the vicinity of differentiating primodia and of staminate organs by low auxin levels. Conversely, the days to first flowering was influenced by the application of NPK fertilizers. The maximum number of days to first female flowers (48 days) was observed in $N_0P_0K_0$ treatment while minimum of days to flowering (44 days) was found with $N_{90}P_{60}K_{60}$ treatment. It could be that in control ($N_0P_0K_0$) and with $N_0P_{45}K_{60}$ treatment, the plants were not vigorous or slow growing. Plant required certain minimum of vegetative growth before flowering where slow growing plant took more days to reach that minimum limit. While the maximum N doses (120 kg ha^{-1}) rendered the plants more vegetative growth and delayed flowering (Ali *et al*., 1995). Similarly, appearance of first flowering was delayed in $N_{90}P_0K_{60}$ treatment plants which could be due to phosphorus deficiency or low P content in plant as P influences on flower formation in plants (Gunes and Inal, 2009).

Significantly higher number of female flower was found by the applications of mineral nutrients. The interaction effect of mineral nutrients and plant growth regulators significantly increased the total number of female flowers. The increased number of female flowers can be attribute to physiological and biochemical changes caused by exogenous application of plant growth regulators and mineral nutrients.

Application of NAA and Ethophon increased the total production of female flowers plant^{-1}. The action of NAA increasing the average number of pistillate flowers and reducing male flowers can be explained that NAA increased endogenous levels of auxins and inhibitors resulting the increased female tendency in plant.

Application of Ethophon caused a shift towards femaleness by suppressing staminate flowers. Increase in the number of female flowers with both at Ethophon 150 and 300 ppm might be due to their suppressing effect on male flower production probably by encountering gibberellins effect as has been shown by Friedlander *et al*. (1977). Sreeramulu (1987) reported that femaleness of sponge gourd induced by Ethophon was due to increase the content of endogenous auxin. He also stated that ethrel induced sex expression was auxin mediated. Ethophon 150 ppm proved to be superior to Ethophon 300 ppm in inducing higher number of female flowers. It is assumed that the increase in concentrations of Ethophon to a certain limit the number of female flowers was increased thereafter it declined. It is stated that ethrel treatments that resulted in flower induction were invariably associated with increased ethylene production up to specific concentration. Production of high ethylene concentration showed on male flowers increasing trend and this increased the sex ratio compared to the lower concentration. The application of mineral nutrient (NPK) and plant growth regulators significantly produced maximum fruit yield in bitter gourd. The highest fruit yield was found by the exogenous application of Ethophon 150 ppm with NPK @ 90, 45 and 60 kg ha^{-1}, respectively. The possible reason for increased of yield was higher number of primary branches, number of fruit plant^{-1}, average weight fruit^{-1} and the higher number of primary branches resulted in higher number of pistillate flower, consequently maximum fruit yield. It might be due to Ethophon which increased the primary branches, shifting femaleness and increasing average fruit diameter (Gedam *et al*., 1998; Tolentino and Cadiz, 2005). Arora *et al*. (1985) also reported the increase in fruit yield with N and P application in sponge gourd and improvement in fruit yield owing to its increased branching, number of female flowers, reduced sex ratio, maximum number of fruits and weight fruit^{-1} and increased fruit length and diameter.

CONCLUSION

Application of NPK fertilizers and plant growth regulators significantly induced synchrony of male-female flowers including better fruit setting and higher fruit yield in small sized bitter gourd. Additionally, it is also evident that N90-P45-K60 fertilization along with GA3 and Ethophon spraying may improve both the synchronized flowering and yield status in cucurbits.

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