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RESEARCH ARTICLE

Efficacy of Plant Growth Regulators on Sex Expression, Earliness and Yield Components in Bitter Gourd

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ABSTRACT

Bitter gourd is an important vegetable among cucurbits cultivated extensively on a commercial scale in Pakistan. Studies were carried out to assess the influence of plant growth regulators (PGRs) at different growth stages on sex expression, fruit and seed yield of bitter gourd cv. Faisalabad Long. Three concentrations each of GA_3 (25, 50 & 75 ppm), Ethrel (400, 500 & 600 ppm), and NAA (50, 100 & 150 ppm) were applied at three different stages namely S_1 (2-leaf stage), S_2 (2-leaf and flower initiation stage) and S_3 (2-leaf, flower and fruit initiation stage). Application of GA_3 @ 25 ppm significantly reduced number of days to first flower (40 days) and first harvest (54 days) at S_3. Similarly male to female flower ratio was lowest (11.83) in plants sprayed with GA_3 @ 75 ppm at S_1 while fruit set percentage was highest (90%) with similar application at S_2; however, both fruit length and fruit diameter were highest with similar dose in plants sprayed at S_2. Number of fruits and seed yield vine^{-1} was significantly higher among all the PGRs (GA_3, ethrel and NAA) when plants were sprayed with NAA @ 100 ppm at S_2 and S_1, respectively. Overall results revealed that application of NAA proved to be better for different yield and yield related traits in bitter gourd.

INTRODUCTION

Bitter gourd (*Momordica charantia* L.), from *Cucurbitaceae* family, is also known as balsam pear, bitter melon, bitter cucumber, and African cucumber (Heiser, 1979). Like other cucurbits, maleness is one of the major obstacles in bitter gourd which significantly reduces the fruit and seed yields. Plant growth regulators (GA_3, NAA and Ethrel) a new generation of agrochemical, when added in small amounts; modify the natural growth right from seed germination to senescence in the crop plants. Flowering behavior varies with cultivar, climatic conditions, and cultural practices (Deshpande et al., 1979). The average ratio of staminate to pistillate flowers in monoecious lines throughout the flowering period is typically 50:1 (Rasco and Castillo, 1990), but ratios can vary dramatically 9:1 to 48:1 (Dey et al., 2005).

Sex expression is a complex characteristic in plants and is influenced by genetic, environmental and hormonal factors. PGRs are chemical compounds that alter plant growth and development by modifying natural hormonal action. Some PGRs are naturally occurring hormones, while others mimic or interfere with the action of natural plant hormones. They are considered as a new generation agrochemicals after fertilizers, pesticides and herbicides and are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates thereby helping better fruit set (Deepthi et al., 2008). Similarly; in bitter gourd, it is possible to increase the yield level by increasing the fruit set percent by use of some growth regulators. Use of PGRs might be a useful alternative to increase crop production. Recently, there has been global realization about the important role of PGRs in increasing crop yield. Gibberellic acid is an important growth regulator that may have many uses to modify the growth, yield and yield contributing characters of plant (Rafeekher et al., 2002).

The principle in sex modification in cucurbits lies in altering the sequence of flowering and sex ratio. Besides the environmental factors, endogenous levels of auxins, gibberellins, ethylene and ascorbic acid, at the time and the set of ontogeny determine the sex ratio and sequence of flowering (Deepthi et al., 2008). Exogenous application of plant growth regulators can alter the sex ratio and sequence, if applied at 2 or 4 leaf stage which is the critical stage for suppression or promotion of either sex (Shinde et al., 1994). Hence, modification of sex to desired direction has to be manipulated by exogenous application of plant growth regulators (Rudich, 1983). Foliar application of gibberellic acid (GA_3) treatment can dramatically increase gynoecy in bitter gourd, while cycocel (CCC; chlormequat) promotes staminate flower development (Wang and Zeng, 1996). Moreover, the appearance of the first staminate flower is delayed and pistillate flower initiation is promoted by relatively low concentrations of GA_3 (Wang and Zeng, 1997; Akter and Rehman et al., 2010). Though the PGRs have great potentialities to influence plant growth morphogenesis, its application and accrual assessments have to be judiciously planned in terms of optimal concentrations, stage of application, species specificity, seasons which constitute the major impediments in PGRs applicability. Therefore, there is dire need to generate precise information for local farming community to assess the impact of PGRs at different growth stages to achieve better growth habits, fruiting and yield in bitter gourd. The objective of this study was not only to maximize bitter gourd productivity and seed yield but also to induce femaleness by the use of different PGRs.

MATERIALS AND METHODS

Seed of commercially cultivated bitter gourd variety viz. Faisalabad Long, was obtained from market while Plant growth regulators (GA_3, Ethrel and NAA) were obtained from Pakistan Scientific Store (Pvt.) and Bayer Crop Science (Pvt.) Ltd, Pakistan. Seeding was done on raised beds (20 x 6 feet SI units cm or m) and plants were spaced at 1 ft apart. After soil nutrient analysis, fertilizers were applied @ 150, 125 and 125 kg ha^{-1} respectively for nitrogen, phosphorus and potash, respectively. One third of Nitrogen (N) while full dose of phosphorus and potash fertilizer was applied at sowing time while remaining N was applied throughout the season as needed by the crop. Standard plant protection measures were followed as and when required. The experiment was laid out following Randomized Complete Block Design (RCBD) with factorial arrangements and replicated three times with 10 plants in each replication. Growth regulator application treatments include T_o = (Control; No application of any plant growth regulator), T_1 (GA_3 25 ppm), T_2 (GA_3 50 ppm), T_3 (GA_3 75 ppm), T_4 (Ethrel 400 ppm), T_5 (Ethrel 500 ppm), T_6 (Ethrel 600 ppm), T_7 (NAA 50 ppm), T_8 (NAA 100 ppm), T_9 (NAA 150 ppm) applied at three different stages S_1 (2-leaf stage), S_2 (2-leaf and flower initiation stage) and S_3 (2-leaf, flower and fruit initiation stage). Data was collected on different reproductive traits such as days to first flower, male to female flower ratio, fruit set %age, number of days taken to first harvest after sowing, fruit and seed yield etc. Analysis of variance of the data from each attribute computed using the STATISTIX. The least significant difference test at 5% level of probability was used for the differences among means (Steel et al., 1997).

RESULTS AND DISCUSSION

Number of days taken to first flowering (days)

Data regarding days to first flowering indicated significant differences between growth regulators treatments and it was observed that T_5 took maximum (50.67) number of days to first flowering while it was lowest in T_0 (41 days) plants. All other treatments behaved statistically alike expect T_6 and T_0 with 48 and 46 days, respectively. Among different growth stages, number of days taken to first flowering were maximum when plants were sprayed at S_2 and S_3 respectively and both stages behaved statistically alike while it was minimum at S_1 stage (Table 1). The interactive effect between plant growth regulators and growth stage was significant and number of days taken to first flowering was maximum (55 days) in T_5 plants at S_3 while it was lowest (40 days) in T_6 at S_1 and T_1 (42 days) at S_3 (Fig. 1). These results indicated that application of Ethrel delayed flowering in bitter gourd. Application of GA_3 (400 mgl^{-1}) stimulated the number of both pistillate and staminate flowers (Chaudhry and Khan , 2006). Present results support the findings of Sure et al. (2013) that spraying of gibberellin at (25, 50 and 75 mgl^{-1}) during 4 leaf stage significantly affected the vegetative and reproductive growth (flowering) which resulted in increased fruit as well as seed yield in medicinal pumpkin. Pankaj et al. (2005) recorded substantial variation in the number of days for first male and female flowers over control in bottle gourd. These results are in line with Hossain et al. (2006) who recorded minimum days to first flower in bitter gourd using GA_3 @ 25 ppm was applied. Similarly, Dixit et al. (2001) observed early flowering in watermelon in plants sprayed with GA_3 (25 and 50 ppm), which consequently resulted in early yield.

Male to female flower ratio

The effect of PGRs on sex expression is well documented in other *cucurbitaceous* crops. Sex expression such as flowering time, sex of flowers, number of flowers (male & female) and sex ratio, in cucurbitaceous plants are determined by gene and environment. All growth regulator treatments differed

Table 1: Influence of plant growth regulators on earliness, sex expression, fruit and seed yield in bitter gourd at different growth stages

Treatments (T)	Days to first flower (days)	Male to female Ratio	Fruit set (%)	Days to first harvest (days)	Single fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Number of fruits vine^{-1}	Fruit yield vine^{-1}	Seed yield vine^{-1}
T_o = Control	46.00c	49.87a	60.06f	60.00c	43.60g	11.33c	4.00d	4.11d	0.22e	0.003e
T_1 = GA_3 25 ppm	41.00d	25.59b	85.48bc	55.33ef	112.36bc	18.33a	11.02ab	9.33ab	1.05ab	0.025cd
T_2 = GA_3 50 ppm	41.67d	20.86cd	85.98bc	56.00def	113.34b	17.83ab	11.65a	8.00b	0.91bc	0.031bc
T_3 = GA_3 75 ppm	41.33d	18.05e	87.84ab	57.00d	118.10a	18.50a	11.71a	9.33ab	1.10a	0.037ab
T_4 = Ethrel 400 ppm	48.33b	16.42ef	84.13c	62.67b	108.48e	16.67ab	9.49bc	7.67bc	0.87bc	0.029bc
T_5 = Ethrel 500 ppm	50.67a	14.64f	80.56d	62.00b	105.09f	17.00ab	9.70bc	7.67bc	0.82cd	0.019d
T_6 = Ethrel 600 ppm	48.00bc	17.08e	76.85e	65.33a	109.45de	16.17b	9.26c	6.00cd	0.68d	0.024cd
T_7 = NAA 50 ppm	41.33d	20.37d	85.61bc	55.00f	112.54b	17.83ab	10.69abc	8.00b	0.91bc	0.042a
T_8 = NAA 100 ppm	41.00d	22.58c	88.67a	57.33d	110.07de	17.83ab	10.93ab	10.33a	1.16a	0.042a
T_9 = NAA 150 ppm	41.67d	21.90cd	86.99ab	56.78de	110.59cd	18.00ab	10.85abc	9.00ab	0.99abc	0.035ab
Growth Stage (GS)										
S_1=2-leaf stage	42.60b	21.74b	82.97b	58.13b	106.82a	17.40a	10.05a	9.80a	1.05a	0.032a
S_2=2-leaf and flower initiation stage	44.80a	25.05a	84.45a	58.90ab	107.70a	17.55a	10.58a	8.00b	0.89b	0.031a
S3 = 2-leaf, flower and fruit initiation stage	44.90a	21.41b	79.23c	59.20a	98.57b	15.90b	8.89b	6.30c	0.68c	0.024b
Interactive effect										
T x GS	*	*	*	*	*	*	*	*	*	*

Mean having different letters differ significantly at 5% probability; *= significant

significantly for this reproductive trait (Table 1). Male to female flower ratio was highest in control plants while it was lowest in T_5. Similarly T_4 was statistically at par with T_5. As for as the effect of different growth stages on male to female ratio is concerned, it was maximum in plants sprayed at S_2 stage while minimum at S_1 and S_3 stage and both stages behaved statistically alike. The interactive effect between plant growth regulators and growth stage was significant and male to female flower ratio was higher (56.5) in control plants at S_1 stage while it was lowest in T_3 plants (11.83) at S_1 (Fig. 2). These results are in accordance with Jadav et al. (2010) revealed that Ethrel @ 200 ppm was most effective in converting femaleness, producing more number of branches and increasing the yield in cucumber. The sexual differentiation is controlled by endogenous levels of auxins, which developed flowering primordia and during flowering act as anti-gibberellin substance. This anti-gibberellin effect suppressed staminate flowers and promotes more number of pistillate flowers (Sulochanamma, 2001).

Fruit set percentage (%)

In recent past, plant growth, flowering and yield have been manipulated through different growth regulating substances. Data regarding fruit set percentage revealed significant differences among different growth regulator treatments and highest fruit set percentage was recorded in T_8 while it was on the lower side in control plants. Similarly T_8 was statistically at par with T_3 and T_9. Among different growth stages, fruit set percentage was maximum when plants were sprayed at S_2 for this parameter while it was minimum at S_1 and S_3 (Table 1). The interactive effect between plant growth regulators and growth stage was significant and fruit set percentage was maximum (90 %) in T_3 plants at S_2 while it was lowest (50%) in control plants at S_3 stage (Fig. 3). Dostogir et al. (2006) concluded that application of GA_3 at pre-flowering stage in bitter gourd plant significantly influenced flowering behavior and fruiting characteristics. They recorded highest fruit set per plant (84.51%) in plants sprayed with GA_3 at 70 ppm while it was lowest (63.41) with GA_3 (20 ppm) in bitter gourd.

Days to first harvest (days)

Growth regulator treatments differed significantly for days taken to first harvest and maximum days were recorded in T_6 while minimum in T_7. Similarly T_1, T_2 were statistically at par with T_7. Among the different growth stages, maximum days taken to first harvest were observed in plants sprayed at S_3 and it was statistically at par with S_2; however, it was minimum at S_1 (Table 1). The interactive effect between plant growth regulators and growth stage was significant and days to first harvest were highest (67 days) in T_6 plants at S_3 while it was lowest (54 days) in plants from T_1 at S_3 (Fig. 4). These results are in line with the findings of Gedam et al. (1998) that application of NAA @ 50 ppm showed the earliest fruit maturity in bitter gourd. Similarly, Marbhal et al. (2005) observed that growth regulator treatments significant influenced number of days required to harvest mature fruits from flowering. They reported that ethephon treatment reduced number of days (33.8 days) as compared to control (39.2 days). However, slight reduction was seen in plants sprayed with NAA (37.3 days).

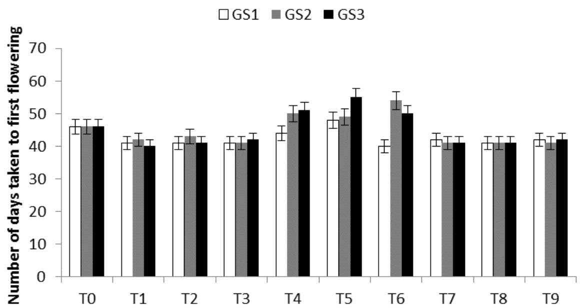

Fig. 1: Interactive effect of plant growth regulators and growth stages on days taken to first flowering in bitter gourd

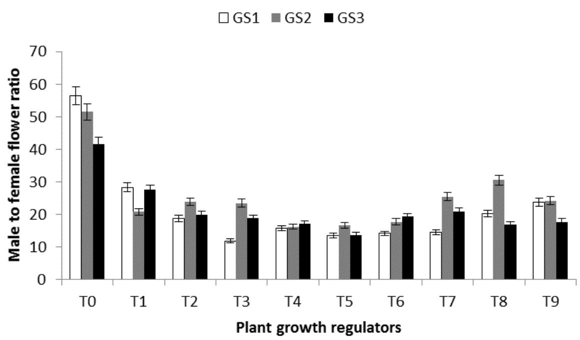

Fig. 2: Interactive effect of plant growth regulators and growth stages on male to female flower ratio in bitter gourd

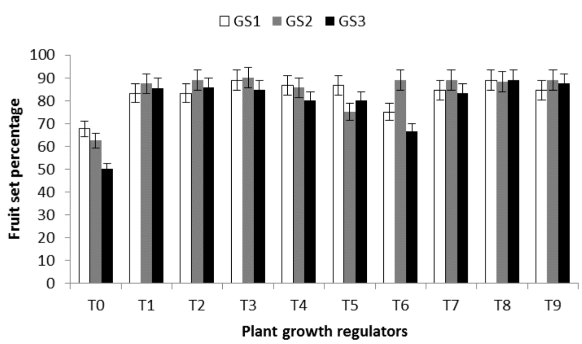

Fig. 3: Interactive effect of plant growth regulators and growth stages on fruit set percentage in bitter gourd

Single fruit weight (g)

Data on this reproductive trait revealed significant differences between growth regulator treatments for this trait and single fruit weight was highest in T_3 while it was lowest in control. S_1 and S_2 showed superiority for maximum single fruit weight; both stages behaved statistically alike while fruit weight was less in case of S_3 (Table 1). The interactive effect between plant growth regulators and growth stage was significant and fruit weight was maximum (125.12 g) in T_4 plants at S_2 while it was lowest (40.69 g) in control plant at S_2 (Fig. 5). These results showed that single fruit weight was maximum at higher doses of GA3 (75 ppm) but Dostogir et al. (2006) concluded that maximum fruit weight was recorded at lower doses of GA_3 (40 ppm) while it decreased significantly when GA_3 was applied @ 85 ppm in bitter gourd. There are several reports that PGRs significantly increased fruit weight in cucurbits. Yasuyoshi and Yoshiyuki (1995) revealed that the application of NAA @ 150 ppm at 2 and 4 true leaf stages increased the average fruit weight in watermelon. Similarly, foliar application of NAA (50 ppm) and boron (4 ppm) increased fruit weight in bitter gourd (Gedam et al*.*, 1998).

Fruit length (cm)

Significant differences were observed between growth regulator treatments for this trait. Both T_1 and T_3 were statistically alike for this trait with highest fruit length while it was lowest in fruits from T_0 plants. All other treatments were statistically at par with each other except T_6. Among different growth stages, maximum fruit length was recorded in S_1 and S_2; both stages behaved statistically alike while it was on the lower side at S_3 (Table 1). The interactive effect between plant growth regulators and growth stage was significant and fruit length was maximum (20.5 cm) in T_7 plants at S_2 while it was lowest (10.5 cm) in fruits from control plants at S_3 (Fig. 6). Present results revealed that the size of bitter gourd fruit varied considerably under different concentrations and stages of the growth regulators. Prabhu and Natarajan (2006) recorded maximum fruit length in Ivy gourd when GA3 and NAA were applied @ 100 and 400 ppm respectively. This increase in fruit length might be due to activating cell division and cell elongation along with increasing the metabolic activity.

Fruit diameter (cm)

Table 1 depicted significant variation among all the growth regulator treatments for this quality trait. Fruit diameter was highest in T_2 and T_3; both these treatment were statistically similar while it was lowest in control plants. Similarly, T_2 and T_3 were statistically at par with T_1, T_7, T_8 and T_9. Among different growth stages, both S_2 and S_1 respectively depicted significantly higher values for this trait than S_3. Both stages were statistically similar for this trait while minimum value regarding fruit diameter was recorded in fruits of S_3. The interactive effect between plant growth regulators and growth stage was significant and fruit diameter was maximum (12.96 cm) in T_7 plants at S_2 and T_3 plants at S_3 while it was lowest (3.97 cm) in control plants at S_2 (Fig. 7). Similar results were reported by Gedam et al. (1998) and Dostogir et al. (2006) that both GA_3 and NAA significantly increased fruit diameter in bitter gourd.

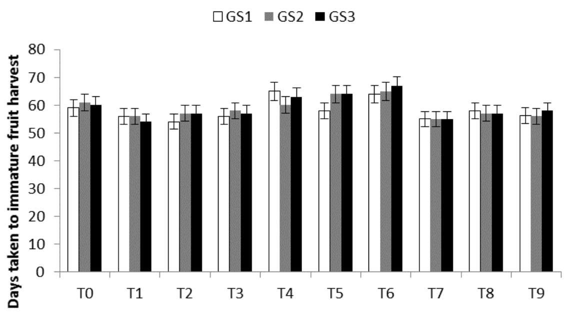

Fig. 4: Interactive effect of plant growth regulators and growth stages on days to taken first harvest in bitter gourd

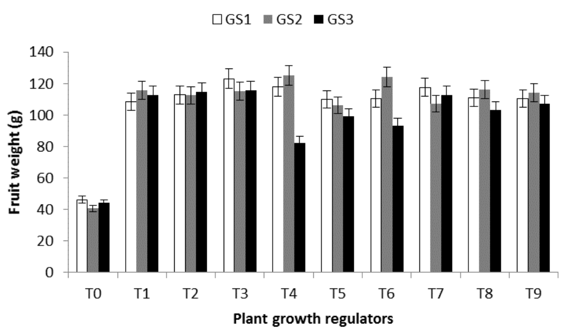

Fig. 5: Interactive effect of plant growth regulators and growth stages on single fruit weight (g) in bitter gourd

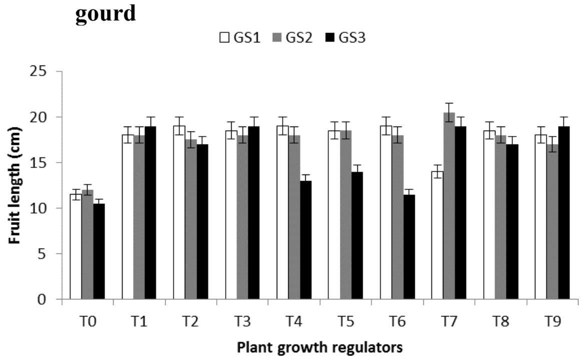

Fig. 6: Interactive effect of plant growth regulators and growth stages on fruit length (cm) in bitter gourd

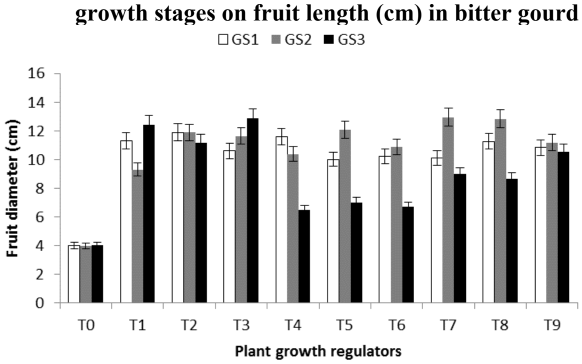

Fig. 7: Interactive effect of plant growth regulators and growth stages on fruit diameter (cm) in bitter gourd

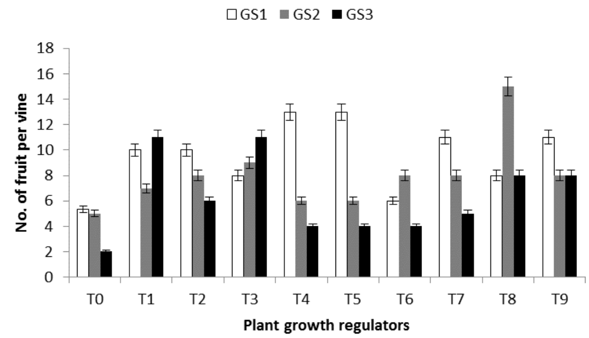

Fig. 8: Interactive effect of plant growth regulators and growth stages on number of fruit per vine in bitter gourd

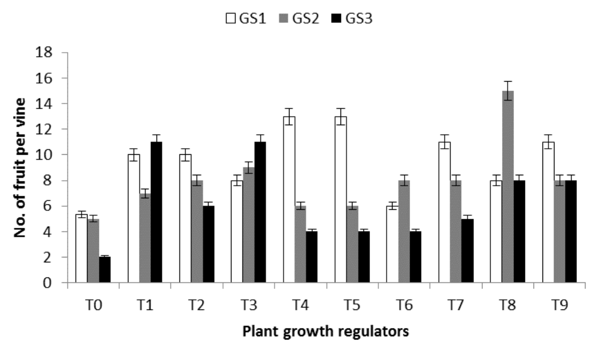

Fig. 9: Interactive effect of plant growth regulators and growth stages on fruit yield vine^{-1} (kg) in bitter gourd

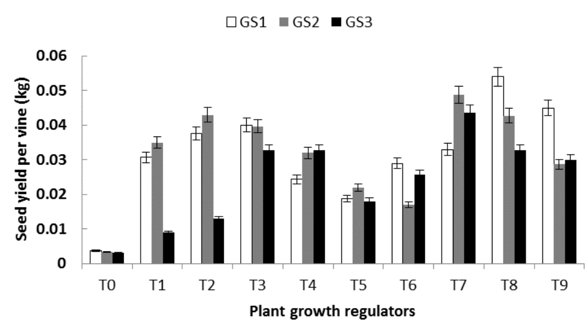

Fig. 10: Interactive influence of plant growth regulators and growth stages on seed yield vine^{-1} in bitter gourd

Number of fruits vine^{-1}

Table 1 showed that application of plant growth regulators significantly increased number of fruits vine^{-1}. Number of fruits vine^{-1} was highest in T_8 while it was number of fruits were found in control. Similarly T_1, T_3, T_9 were statistically at par with T_8. As for as the effect of different growth stages on number of immature fruit vine^{-1} is concerned, all stages differ significantly with each other and maximum fruits per vine were recorded at S_1 (Table 6). The interactive effect between plant growth regulators and growth stage was significant where maximum (15.00) number of fruits vine^{-1} were observed in T_8 plants at S_2 while lowest number of fruits per vines were found (2.00) in control plants at S_3 (Fig. 8). These results are in line with Hossain et al. (2006) who recorded the maximum number of fruit plant^{-1} when GA_3 (25 ppm) was applied in bitter gourd. Similarly, Hidayatullah et al. (2012) recorded maximum number of fruits in bottle gourd by exogenous application GA_3 @ 30 µmol $^{-1}$.

Fruit yield vine^{-1} (kg)

The ultimate economic product of any crop is yield that is determined mainly by fruit weight and number of fruits per plant. Plant growth regulators have significant effect on yield and fruit characteristics in cucurbitaceous crops (Akter and Rehman, 2010). Results of present study revealed that growth regulator treatments differ significantly with respect to fruit yield vine^{-1} and highest yield was recorded in T_8 and T_3 plants respectively while it was lowest in control. Both T_8 and T_3 were statistically at par with T_1 and T_9. Among different growth stages, fruit yield vine^{-1} was highest at S_1 for while it was lowest at S_2 and S_3 respectively (Table 1). The interactive effect between plant growth regulators and growth stage was significant and fruit yield vine^{-1} was maximum (1.75 kg) in T_8 plants at S_2 while it was lowest (0.19 kg) in control at S_3 (Fig. 9). These results gave clear indication about the supremacy of NAA @ 100 ppm at S_2 among all other treatments in increasing bitter gourd yield. Present results support the findings of Marbhal et al. (2005) that the fruit yield in bitter gourd was increased by the application of NAA @ 50 ppm as compared to control. Sure et al. (2012) that PGRs and planting method had significant effects on vegetative, flowering fruit and seed yield. They concluded that GA_3 @ 25 ppm in four leaf stage at trellis method could be a suitable treatment for enhancing growth and yield of medicinal pumpkin.

Seed yield vine^{-1} (kg)

All growth regulator treatment significantly increased seed yield when compared with control plants (Table 1). Highest seed yield vine^{-1} was found in T_7 and T_8 while it was lowest in fruit from T_0 plants. Similarly, T_7 and T_8 were statistically at par with T_3 and T_9. Among different growth stages, seed yield vine^{-1} was maximum at S_1 and S_2 and both stages behaved statistically alike while minimum seed yield was recorded at S_3 (Table 1). The interactive effect between plant growth regulators and growth stage was significant and seed yield vine^{-1} was maximum (0.054 kg) in T_8 at S_1 while it was significantly on the lower side (0.003 kg) in control at S_2 (Fig. 10). These results indicated that application of NAA (100 ppm) at two leaf stage could be useful to maximize seed yield in bitter gourd. The increased number of female flowers, fruit set and increased metabolic activity leading to higher translocation of metabolites from source to sink points which resulted in better development of seed in bitter gourd (Gedam et al., 1998).

Conclusion

From these results it can be concluded that all PGRs treatments differed significantly for all the traits with each other and control plants at different stages. Among different treatments, GA_3 @ 25 ppm resulted in early flowering and fruit maturity in bitter gourd when applied at S_3 while application of GA_3 @ 75 ppm significantly reduced male to female ratio at S_1 while increased fruit length and fruit diameter at S_2. However, significant increase in fruit and seed yield was achieved in plants sprayed with NAA @ 100 ppm at S_2 and S_1 respectively.

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