INFLUENCE OF GIBBERELLIC ACID ON THE GROWTH AND YIELD OF BITTER GOURD IN SEMI-ARID CLIMATE

SHAH, S. A. A.[1,2,3*] – AYUB, G.[2] – SHAH, S. A. A.[1,4] – KHAN, M.[2,5] – AYAZ, A.[2,6] – ZEB, S.[7] – AHMAD, S.[2] – AZEEM, I.[2] – SUN, N.[1*] – XU, M. G.[1]

[1]*Key Laboratory of Arable Land Quality Monitoring and Evaluation, Ministry of Agriculture and Rural Affairs, Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences, Beijing 100081, China*

[2]*Department of Horticulture, The University of Agriculture, Peshawar, Pakistan*

[3]*Department of Vegetable Sciences, College of Horticulture, China Agriculture University, Beijing, China*

[4]*Department of Soil and Environmental Sciences, The University of Agriculture, Swat, Pakistan*

[5]*College of Horticulture, Northwest A&F University, Yangling, China*

[6]*College of Horticulture, Nanjing Agriculture University, Nanjing, China*

[7]*Hazara Agriculture Research Station, Abbottabad, Pakistan*

**Corresponding authors*
e-mail: syed_aizaz@aup.edu.pk; sunnan@caas.cn

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Abstract. Bitter gourd (*Momordica charantia* L.) is an important cucurbitaceous vegetable due to its high nutritional value. Different growth regulators were used for the better yield of bitter gourd but the application of gibberellic acid as foliar spray is less addressed. An experiment was conducted to investigate the effect of gibberellic acid (GA3) on the yield and growth stages of bitter gourd at Horticulture Research Farm, The University of Agriculture Peshawar, Pakistan during summer 2016. Gibberellic acid concentrations (GA3) 0 ppm, 30 ppm, 60 ppm, and 90 ppm were applied at different leaf stages i.e., 2-4 leaves, 5-7 leaves, and 8-10 leaves. Results revealed that both the growth and yield were significantly influenced by the application of GA3 concentrations at different growth stages. Furthermore, the use of 90 ppm GA3 concentration improved the minimum male to female ratio (2.19), maximum number of fruits plant^{-1} (20.22), fruit length (15.64 cm), fruit diameter (3.51 cm), fruit weight plant^{-1} (137.82 g), fruit yield kg plot^{-1} (13.98 kg), and total yield tons ha^{-1} (38.83 t) respectively. While 30 ppm GA3 improved the minimum days to first flower (31.22) and minimum days to first harvest (48.56). However, regarding the growth stages 8-10 leaf stage improved minimum days to first flower (33.33), minimum days to first harvest (50.33), minimum male to female ratio (2.81), and maximum number of fruits plant^{-1} (18.50), number of branches plant^{-1}(4.67), fruit length (15.00 cm), fruit diameter (3.29 cm), fruit weight plant^{-1} (137.19 g), fruit yield kg plot^{-1} (12.79 kg), and total yield tons ha^{-1} (35.53 t). Overall gibberellic acid at 90 ppm concentration at 8-10 leaf stages was found beneficial for better growth and yield of bitter gourd under the semi-arid climatic condition of Peshawar.
Keywords: *bitter gourd, yield, plant growth regulator, morphological traits, fruit quality*

Introduction

Bitter gourd (*Momordica charantia* L.) or Karela (Pakistan), is an important member of the family Cucurbitaceae, is used as a food, and has medicinal importance as well. Bitter gourd grows in various tropical regions of the world i.e., India, Malaya, China, tropical

Africa, the Middle East, America (Kubola and Siriamornpun, 2008) and it is one of the most important summer vegetables in Pakistan as well. Generally, the bitter gourd growing season in Pakistan and India is January to June and nowadays, it is usually grown as an annual crop (Saleem et al., 2014). An optimum temperature of 25-28 °C is required for the germination of bitter gourd seeds and in the Pakistani region, the temperature remains high except for the short winter season. (Baig et al., 2020). Bitter gourd is also broadly cultivated in Pakistan. The total area under production is 6080 ha with 56239 tons, while in KPK, the total production is 6483 tons in an area of 894 ha (MINFAL, 2009). Bitter melon is a bitter tasting herbaceous plant cultivated in tropical and subtropical regions of many countries. Traditionally, bitter melon is used in different countries as a folk medicine. The fruits are also used as a side dish in southeast Asia (Sur et al., 2020). Bitter gourd has a higher nutritional value. Bitter gourd contains proteins, vitamins, carbohydrates, and minerals. (Palada and Chang, 2003). Bitter gourd lowers the blood sugar and is considered to be useful for diabetic treatment. It is also used for treatment of cancer because of its anti-noxious possessions (Grover and Yadav, 2004). Considerable modification in nutrients, counting carbohydrates, calcium, magnesium, protein, zinc, iron, ascorbic acid, and phosphorus have been reported (Sajan and Shauyla, 2021). The natural products are cooked to vegetables, stuffed, blended, broiled, or included in little volumes in beans and soups to give a tiny bit sharp flavor (Reyes et al., 1994). Bitter gourd has been utilized for years in the early traditional therapy of India, China, Africa, and Latin America. Bitter gourd cuttings hold anti-hepatotoxic, anti-microbial anti-oxidant, anti-viral, and anti-ulcerogenic stuffs furthermore, at the same time have the power to degrade blood glucose (Sajan and Shauyla, 2021). The leaves of bitter gourd are also used traditionally in the care of breast cancer (Dandawate et al., 2016). Bitter gourd is particularly developed in the spring, summer, and blustery seasons, with some winter creation in subtropical atmospheres. From January to June, it is cultivated in the plain areas (Adhikari et al., 2021). Bitter gourd completes abundantly in perfect sunshine and is exchangeable to an extensive chain of soil for all that develops exceptionally in sandy loam and well-drained. It develops in a soil medium depth i.e. (50-150 cm), resembling most cucurbits. 6.0 to 6.7 pH is best for bitter gourds, alkaline soil can be tolerated by bitter gourds up to pH 8.0 (Baig et al., 2020: Behera et al., 2010). Commonly, bitter gourd is cultivated through direct seed sowing. The seed coat is hard so it germinates gradually due to the gentle concentration of H_2O. Its edible portion is picked at its young stage when the peel color turns to dark green with a white inner surface surrounding the seeds. When the fruit reaches the ripening stage, the skin and central flesh appears bright orange and the seed becomes coated in vivid red arils. (Adhikari et al., 2021). At this stage, the fruits ultimately split open, illuminating the red arils as a means to attract birds for seed dispersion (John et al., 2007). Unlike most fruit, bitter gourd is eaten unripe as the orange flesh has an unpleasant taste and texture, and some studies indicate that the red arils in the fruit can be toxic to children (Morton, 2008). The quality and production of bitter gourd depend on several production factors like fertilizer application, soil, irrigation, climatic conditions and plant growth regulator. Among these factors growth regulator, GA3 is used in the present research because gibberellic acid (GA3) are plant hormones that control growth and affect several changing processes, containing germination, stem elongation, dormancy, flowering, sex expression, enzyme initiation (Bagale et al., 2022). Foliar spray of growth regulators can change sex expression (Shafeek et al., 2016). GA3 (25-100 mg L^{-}intensely raises femaleness in bitter gourds, whereas cycocel (50 to 200 mg L^{-1}) helps in female flower development. Additionally, the arrival of male flowers is late and female flower introduction is promoted by comparatively

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low concentrations of Cycocel, (0.04 to 4 mg/l) (Momin et al., 2007: Wang and Zeng, 1997c). The recent investigation has been planned in light of the significance of the plant growth regulator to beat the constraining development and yield of bitter gourd. The objectives of the study were to assess the response of different levels of gibberellic acid (GA3) concentration on the flowering, fruit set and yield of bitter gourd and also to investigate the best growth stage for foliar application of gibberellic acid (GA3).

Materials and methods

Experimental site characteristics

To study the effect of gibberellic acid on the yield and growth stages of bitter gourd (*Momordica charantia* L.) present field experiment was conducted at Horticulture Research Farm, The University of Agriculture Peshawar, Pakistan during summer (March-August) 2016 (*Fig. 1*). The research farm is located at 34.01°N, 71.35°E, at an altitude of 350 m above sea level in the Peshawar valley. Peshawar is located about 1600 km north of the Indian ocean and has a semiarid climate. The research farm is irrigated by the Warsak canal linked to Kabul River. Soil particle analysis revealed that the texture of soil was clay loam, alkaline (pH 8.2) in nature, calcareous, with a low organic matter content of 8.7 g kg^{-1} (Shah et al., 2020: Amanullah et al., 2009). The climate of the area is semiarid where the mean annual rainfall is very low (300 to 500 mm), 60-70% of which occurs in summer, while the remaining 30-40% rainfall occurs in winter (Amanullah et al., 2016).

Land preparation and crop sowing

The field was ploughed accurately and leveled before seed sowing. Five hand trolleys of FYM were added to the plots and carefully mixed with soil. Bitter gourd cultivar ‘Jaunpuri’ seeds were soaked and then 2-3 seeds were sown at 30 cm plant to plant distance. After the emergence of seedling, thinning was practiced to keep one plant. Row to row distance was kept 2 m. All other agronomic practices i.e., seed bed preparation, irrigations, hoeing and weeding were practiced uniformly to all the plots throughout the growth period for maximum yield. Good quality canal water was used for irrigation and crop protection measures were carried out as and when required throughout the experimental duration.

Experimental design

The experiment was established in randomized complete block design (RCBD) by split plot arrangement having two factors, replicated three times. Three GA3 concentrations along with control were used such as 0, 30, 60 and 90 ppm respectively and these concentrations were applied as foliar spray at three growth (leaves) stages i.e., 2-4, 5-7 and 8-10. Gibberellic acid was dissolved in ethanol and then reached up to the desired volume. The details of the factors are as follows:

Factor A (growth stages)

1. 1st application 2-4 leaf stage
2. 2nd application 5-7 leaf stage
3. 3rd application 8-10 leaf stage

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Factor B (gibberellic acid concentration as ppm)

1. Control
2. 30 ppm GA3
3. 60 ppm GA3
4. 90 ppm GA3

Plant growth, phenological and yield attribute measurements

Data were collected for the following phenological and yield parameters. Early flower appearance was determined by the total number of days from the date of sowing to the appearance of flowers and then was counted and average was calculated. However, early harvesting was determined by counting the days from sowing till first fruit picking. For the determination of male to female flower ratio, the total number of staminate and pistillate flowers was counted and then its ratio was calculated. Furthermore, no of fruits plant^{-1} were determined by selecting randomly and their mean was calculated. In case of number of branches plant^{-1}, plants were randomly selected for each treatment and the total number of branches were counted. However, average fruit length was measured by picking the fruits randomly and was measured in each treatment with measuring tape and after that the average was calculated. In the same way, fruit diameter was also measured with measuring tape. Each fruit was measured at three points and then the average value was calculated. Fruit weight was determined through digital balance. For total yield (t ha^{-1}) first, we calculate the yield plot^{-1} (kg) and then put in the total yield equation, their means were calculated.

$$\text{Yield (t ha}^{-1}) = \frac{\text{Plot yield (Kg)} \times 10000\ \text{m}^2/1000}{\text{Plot area (m}^2)} \qquad \text{(Eq.1)}$$

Figure 1. *Experimental site: Horticulture Research Farm, The University of Agriculture, Peshawar*

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Statistical analysis

Collected data for all the replicated data were analyzed through software Statistix version 8.1 and means were compared by using Fisher's protected least significance difference (LSD) test at 5% level of significance (Steel and Torrie, 1980).

Results and discussion

Days to first flower

It was observed that growth stages and GA3 concentrations (0, 30, 60. 90 ppm) had a significant effect on days to first flowering (*Table 1*). From Mean table Minimum days to first flower appearance (33.33) was observed in plants sprayed at 8-10 leaf stage and late appearance of first flower (35.83) was observed in plants sprayed at 2-4 leaf stage. In case of GA3 concentrations, the earliest first flower (31.22) was recorded at 30 ppm application and late appearance was noted (40.22) in control treatment. Non-significant interactive results were noted. The reason could be initial translocation of plant materials that is critical for blossom improvement because of GA3 application (Khan et al., 2019). The utilization of 25 ppm GA3 reduced the number of days to first bloom (Rosales and Richard, 2018; Ghani et al., 2013). Furthermore, the application of gibberellin at (25, 50 and 75 mg L) essentially influenced the reproductive and vegetative development (blossoming) which brought about expanded fruit and pumpkin seed yield (Pal, (2019). Pankaj et al. (2005) verified significant differences in the quantity of days to first male and female flower over control in bitter gourd. Least days to first blossom in utilizing GA3 at 25 ppm was noted in bitter gourd by Hossain et al. (2006). Furthermore, Dixit et al. (2001) noted early blossoming in watermelon by sprinkling with GA3 (25 and 50 ppm), which therefore brought about early yield.

Number of branches plant^{-1}

The obtained results revealed that stages and concentrations had a significant effect on the number of branches plant^{-1} (*Table 1*). Highest no of branches plant^{1} (4.67) was seen at 8-10 leaf stage while lowest no of branches plant^{-1} (3.50) was recorded at 2-4 leaf stage. Comparing means of concentrations maximum no of branches plant^{-1} (5.00) was recorded at 60 ppm GA3 concentration while least no of branches plant^{-1} (3.22) was observed in control treatment. However, interaction was non-significant. Application of GA3 resulted in higher vegetative growth as foliar application of gibberellins has been generally adopted because these hormones are naturally synthetized in young leaves and from there are subsequently transported throughout the plant moving both acropetally and basipetally (Miceli et al., 2019a,b; Dayan et al., 2012). The expansion in branches might be credited to improved supplement take-up, higher photosynthetic movement and translocation productivity bringing about quick cell division, lengthening and vegetative development. Increases in branches were also recorded by Khandaker et al. (2018) with application of GA3 and other growth regulators.

Days to first harvest

Mean data shows that days to first harvest was strongly influenced by GA3 concentrations and growth stages (*Table 1*). Regarding mean data, minimum days to first harvest (50.33) was observed in plants sprayed at 8-10 leaf stage and later first

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harvest (54.25) was recorded in plants sprayed at 2-4 leaf stage. Comparing the mean of concentrations minimum days to first harvest (48.56) was observed at 30 ppm GA3 and maximum (56.67) was found in control. It might be due to Early first flower appearance may complete all their stages. Ghani et al. (2013) stated that use of GA3 at 25 ppm essentially lessened the number of days to harvest. These outcomes are in accordance with the results of Gedam et al. (1998) that utilization of NAA at 50 ppm established the earliest natural product enlargement in bitter gourd. Marbhal et al. (2005) surveyed that PGR treatment affected the number of days required for fruit to develop from blooming. They stated that treatment of ethephon diminished the number of days when contrasted with control. In any case, a slight decrease was found in plants dropped with NAA.

Male to female flower ratio

Mean data showed significant variation in male and female flower ratio. Lower male to female flower ratio (2.81) was recorded in plants which were sprayed in 8-10 leaf stage and maximum male to female flower ratio (3.23) was recorded in plants sprayed at 2-4 leaf stage. While in case of concentrations, minimum male to female flower ratio (2.19) was recorded for bitter gourd at 90 ppm GA3 and highest (3.70) was seen in control treatment. The sexual separation is maintained by various levels of auxins, which created primordia of flower and amid blooming and performed as anti-gibberellin substance. This hostile to gibberellin impact stifled staminate blooms and advanced a greater number of female flowers (Sulochanamma, 2001). Ghani et al. (2013) reported in bitter gourd that the most minimal (11.83) male to female ratio in plants sprinkled with GA3 at 75 ppm. The after effects of the present review are in conformity with those of James et al. (1990) who concluded that GA3 lessened the to blossom sex proportion in cucumber by diminishing the quantity of male blooms and expanding the female flower. Hidayatullah et al. (2011) also reported that GA3 significantly increased the total number of pistillate flowers in cucumber. Rahman and Karim (1997) however, got similar results by applying 50 ppm GA3 in combination with 100 ppm NAA and 75 ppm TIBA. Singh and Choudhury (1983) reported that ethrel (100 ppm concentration) produced the lowest sex-ratio in bottle gourd.

Number of fruits plant^{-1}

A significant effect of different GA3 concentration applied at different growth stages was observed on the number of fruits plant^{-1}, even though the interactive effect was non-significant. Maximum number of fruits plant^{-1} (18.50) was recorded in plants sprayed with GA3 at 8-10 leaf stage and lowest number of fruits plant^{-1} (14.83) was recorded at 2-4 leaf stage. In case of concentrations, highest no of fruits plant^{-1} (20.22) was recorded at 90 ppm GA3 while least no of fruits plant^{-1} (13.00) was observed in control treatment. Higher number of fruits is due to higher female flower formation. GA3 is responsible for stimulating vegetative development traits conductive to the food synthesis mechanism, hence more food stokes have been found in the treated plants. GA3 level in treated plants was naturally more, which itself has a property of increasing fruiting. GA3 becomes more active in presence of extra plant food and hence the number of fruits seems to have increased or this may be due to the positive correlation of amount of fruits/plant with number of pistillate flowers. Same findings were noted by Hidayatullah et al. (2011) that maximum fruits plant^{-1} was recorded when GA3 were applied as foliar spray.

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Table 1. *Effect of GA3 concentrations at different growth stages of bitter gourd*

GA3 concentrations	Days to flowering	No. of branches	Days to 1st harvest	Male, female flower ratio	No. of fruits
0	40.22 a	3.22 c	56.67 a	3.70 a	13.00 d
30	31.22 d	4.33 b	48.56 d	3.30 ab	15.33 c
60	32.56 c	5.00 a	50.56 c	2.91 b	18.44 b
90	34.44 b	3.78 bc	52.89 b	2.19 c	20.22 a
LSD	1.2426	0.5638	1.7726	0.456	1.4167
Growth stages					
2-4 leaf	35.83 a	3.50 c	54.25 a	3.23 a	14.83 c
5-7 leaf	34.67 b	4.08 b	51.92 b	3.03 ab	16.92 b
8-10 leaf	33.33 c	4.67 a	50.33 c	2.81 b	18.50 a
LSD	1.0261	0.4627	1.7726	0.2566	1.4633
Interaction C × GS	**ns**	**ns**	**ns**	**ns**	**ns**

Means of the same category followed by different letters are significantly different from each other using the LSD test ($P \leq 0.05$). ns stands for non-significant data at 5% level of probability

Fruit length (cm)

The fruit length and growth stages are significantly increased by the application GA3 (*Table 2*). Highest fruit length (15.00 cm) was observed in plants which were sprayed at 8-10 leaf stage, while lowest fruit length (13.33 cm) was noticed at 2-4 leaf stage. However, in case of concentration maximum fruit length (15.64 cm) was observed at 90 ppm of GA3, and minimum (12.52 cm) was noticed in control treatment. Fruit length increased at high concentration of GA3 as a result of cell elongation and division. This increase is because of the highest carbohydrates accumulation owing to superior photosynthesis which enlarge fruit length. These results are similar as reported by Uddain and Hossain (2009), where they stated that the enlargement in length may be because of passing cell division and cell lengthening alongside expanding the metabolic action. Prabhu and Natarajan (2006) reported in IVY gourd (*Coccina grandis* L.) that the most extreme fruit length occurred when NAA and GA3 connected.

Fruit diameter (cm)

A significant effect of different GA3 concentration applied at different growth stages was observed on fruit diameter. Maximum fruit diameter (3.29 cm) was observed in plants sprayed at 8-10 leaf stage. However, minimum fruit diameter (2.91 cm) was noticed in plants sprayed at 2-4 leaf stage. Comparing the mean of concentrations, maximum fruit diameter (3.51 cm) was recorded at concentration of 90 ppm GA3 and minimum (2.79 cm) was noticed in control treatment. This increase is due to greater addition of carbohydrates owing to more photosynthesis which triggered the fruit to increase in diameter. Application of GA3 at different growth stages significantly influenced fruit diameter in the bitter gourd (Uddain and Hossain, 2009). Same consequences were testified by Gedam et al. (1998) and Dostogir et al. (2006) who reported that using GA3 and NAA in bitter gourd positively increased fruit diameter.

Fruit weight (g) plant^{-1}

Data analysis regarding fruit weight show significant results sprayed at various growth stages and GA3 concentrations (*Table 2*). From the mean table maximum fruit

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weight (137.19 g) was observed in plants sprayed at 8-10 leaf stage and minimum fruit weight (124.57 g) was recorded in plants sprayed at 2-4 leaf stage. Comparing the mean of concentrations, maximum fruit weight (137.82 g) was recorded at concentration of 90 ppm GA3 while minimum (123.81 g) was noticed in control treatment. Fruit weight is assigned to gibberellins, by its characteristic virtue which helped the vegetative growth, consequently extra material for fruit enlargement was produced by such plants and fruits with higher weight were achieved. Moreover, the plant anabolic processes are being other causes of higher fruit weight (Uddain and Hossain, 2009). Vijay and Jalikop (1980) also reported the same observations, that a GA3 application in different concentrations significantly improves individual fruit weight. The same results were obtained by Ashrafuzzaman et al. (2010), Rajasekar (2015), that foliar application of GA3 improves the morphological traits and photosynthetic activity, which improve fruit yield per plants.

Table 2. *Effect of GA3 concentrations at different growth stages of bitter gourd*

GA3 concentrations	Fruit weight	Fruit diameter	Fruit length	Fruit yield	Yield (tons)
0	123.81 d	2.79 d	12.52 d	8.05 d	22.37 d
30	129.70 c	2.98 c	13.61 c	9.99 c	27.74 c
60	132.99 b	3.21 b	14.51 b	12.32 b	34.22 b
90	137.82 a	3.51 a	15.64 a	13.98 a	38.83 a
LSD	2.9513	0.1691	0.6939	0.9026	2.5104
Growth stages					
2-4 leaf	124.57 c	2.91 c	13.13 c	9.28 c	25.78 c
5-7 leaf	131.48 b	3.16 b	14.09 b	11.18 b	31.06 b
8-10 leaf	137.19 a	3.29 a	15.00 a	12.79 a	35.53 a
LSD	4.4719	0.1253	0.5146	0.7739	2.2291
Interaction C × GS	**ns**	**ns**	**ns ns**	**ns**	

Means of the same category followed by different letters are significantly different from each other using the LSD test ($P \leq 0.05$). ns stands for non-significant data at 5% level of probability

Fruit yield (kg plot^{-1})

Data regarding fruit yield was significant under GA3 concentration at different growth stages. Highest fruit yield (12.79 kg plot-^{1}) was observed in plants sprayed at 8-10 leaf stage while lowest fruit yield (9.28 kg plot^{-1}) was observed in plants sprayed at 2-4 leaf stage (*Table 2*). While, considering GA3, higher fruit yield (13.98 kg plot^{-1}) was recorded at concentration of 90 ppm GA3 and lower fruit yield (8.05 kg plot^{-1}) was noticed in the plots having no GA3 application. This expansion in yield is credited to the most extreme no of fruit plant^{-1} and greatest weight (g). The application of GA3 at different stages extended the production in muskmelon (Randhawa and Kirtisingh, 1973). Biradar et al. *(*2010) also reported maximum fruit yield in bitter gourd. Hidayatullah et al. (2009) also noted maximum fruit yield in cucumber, sprayed with various GA3 concentrations.

Yield (tons ha^{-1})

Total yield was significantly increased by GA3 application sprayed at various growth stages. Maximum yield (35.53 tons ha^{-1}) was observed in plants sprayed at 8-10 leaf stage, while minimum yield (25.78 tons ha^{-1}) was noted in plants sprayed at 2-4 leaf

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stage. Considering GA3 concentrations, maximum yield (38.83 tons ha^{-1}) was observed at 90 ppm and lowest yield (22.37 tons ha^{-1}) was noticed in control treatment (*Table 2*). This increase in yield is attributed to maximum fruit yield $plot^{-1}$. The application of GA3 at different leaf stages extended the production per hectare in muskmelon (Randhawa and Kirtisingh, 1973). Ghani et al. (2013) reported that PGRs significantly turned out to be better for various yield and yield related attributes in bitter gourd. Related results of high yield were also obtained by Hossain et al, (2006) in bitter gourd. Who stated that application of GA3 improved total yield (*Fig. 2*).

Figure 2. *Different stages of bitter gourd during research*

Conclusion

It was concluded that that foliar application of GA3 at the rate of 90 ppm improved many phenological and yield parameters such as male to female ratio, maximum number of fruits $plant^{-1}$, fruit length, fruit diameter, fruit weight $plant^{-1}$, fruit yield kg $plot^{-1}$, and total yield tons ha^{-1} respectively. Furthermore, the application 30 ppm GA3 was found to be good and improved the minimum days to first flower and minimum days to first harvest. However, regarding the growth foliar application of GA3 at 8-10 leaf stage were found very significant and improved minimum days to first flower, minimum days to first harvest, minimum male to female ratio, and maximum number of fruits $plant^{-1}$, number of branches $plant^{-1}$, fruit length, fruit diameter, fruit weight $plant^{-1}$, fruit yield kg $plot^{-1}$, and total yield tons ha^{-1}. Overall gibberellic acid at 90 ppm concentration at 8-10 leaf stages was found very beneficial considering the quantity and quality of bitter gourd growth and yield under the semi-arid climatic condition of Peshawar.

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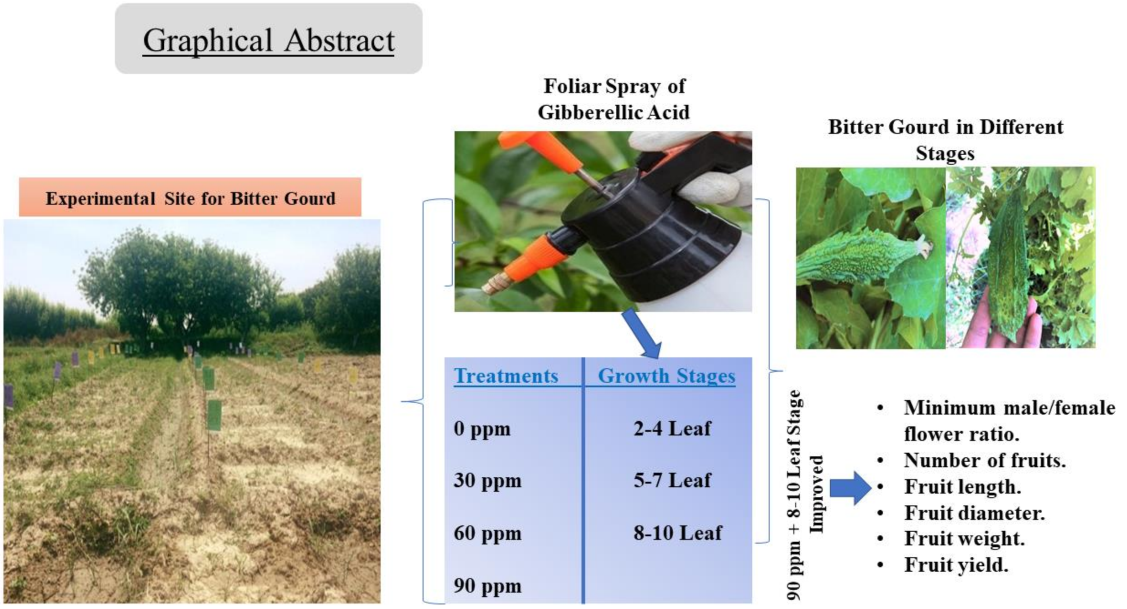
APPENDIX



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