



RESEARCH ARTICLE

EFFECT OF HOMOBRASSINOLIDE ON THE GROWTH OF MUSTARD CROPS GROWN IN SEMI-ARID TROPICS OF NIZAMABAD

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ABSTRACT

The effect of homobrassinolide (HBL) on the shoot growth (length, fresh weight, diameter, and dry weight) root growth (length, fresh weight, diameter, and dry weight) and foliar growth (plant fresh weight, leaves per plant and leaf area) of mustard plants grown in the semi-arid tropics of Nizamabad was studied. The soil in Nizamabad district is saline land black soil wherein the plants usually experience drought and saline stresses. Application of HBL was very effective in stimulating the shoot growth, root growth as well as the foliar growth of mustard plants. The promotion of shoot, root and foliar growth is an indicator that HBL mitigated the negative effect of the semi-arid conditions of the soil.

Key words: Foliar growth, Homobrassinolide, Root growth, Semi-arid tropics, Shoot growth.

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INTRODUCTION

Mustard (*Brassica juncea*) is an oil yielding plant that belongs to the family *Brassicaceae* which is grown in various parts of the globe. Mustard plant has very tiny seeds which are usually used as a condiment. Mustard oil is extracted from the seed which is widely used for cooking, massaging etc. A few varieties of mustard plants have edible leaves that are known as *mustard greens*. It is a well-established fact from time immemorial that plants are the critical components of dietary food chains in which they provide almost all the essential mineral and organic nutrients to humans Grusak and Dellapenna (1999). Brassinosteroids (BRs) are a new type of polyhydroxy steroidal Plant growth regulators (PGRs) with significant growth-promoting influence (Bajguz and Piotrowska-Niczyporuk, 2014; Vardhini, 2017). Mitchell and his co-workers (1970) discovered BRs which were later extracted from the pollen of *Brassica napus* L. by Grove *et al.* (1979). BRs can be classified as C₂₇, C₂₈ or C₂₉ BRs according to the number of carbons in their structure (Vardhini, 2013). Haubrick and Assmann (2006) reported that 60 related compounds have been identified. However, Vardhini *et al.* (2006) reported that brassinolide (BL), 28-homobrassinolide (28-HomoBL) and 24-epibrassinolide (24-EpiBL) are the three bioactive BRs being widely used in most physiological and experimental studies.

BRs are considered ubiquitous in plant kingdom as they are found in almost all the phyla of the plant kingdom like alga, pteridophyte, gymnosperms, dicots and monocots (Bajguz, 2009). Rao *et al.* (2002) stated that BRs are a new group of plant growth hormones that perform a variety of physiological roles like growth, seed germination, rhizogenesis, senescence, etc. and also confer resistance to plants against various abiotic stresses. Though, BRs were initially identified based on their growth promoting activities, subsequent physiological and genetic studies revealed additional functions of BRs in regulating a wide range of processes, including source/sink relationships, seed germination, photosynthesis, senescence, photomorphogenesis, flowering and responses to different abiotic and biotic stresses (Vardhini, 2013). Nizamabad district experiences a tropical dry and wet season with most of the rainfall in June to October. It usually experiences erratic rain fall. The soil is saline land black soil which is deep loamy to clay loam, moderately drained, neutral to alkaline in nature. The semi-arid condition directly poses a threat to the overall yield of the plants as they usually experience drought and saline stresses. The present study is undertaken to understand the effect of application of homobrassinolide (HBL) on the growth of mustard plants in terms of shoot, root and foliage grown in the semi - arid soils of Nizamabad.

MATERIALS AND METHODS

Study Material: The *Brassica juncea* L. var. Indian mustard "Tulasi" was chosen as the study material for the present research investigation. The certified seeds of the *Brassica*

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juncea L. var. Indian mustard “*Tulasi*” were procured from, National Seeds Corporation Limited, Hyderabad, Telangana State, India. Homobrassinolide (HBL) is a commercially available brassinosteroid and was procured from Bahar Agrochem & Feeds Pvt. Ltd, Ratnagiri, Maharashtra, India, Ltd. It is marketed by Godrej Agrovet Ltd., Hyderabad, Andhra Pradesh, India.

Pot Culture: The Plants were grown under natural day length in the semi-arid tropics of Nizamabad town. The mustard seeds were sown in clay pots (40×50 cm in diameter 40×70cm in height) containing fresh sieved black soil which consisted of uniformly mixed soil and vermin-compost in the ratio of 10:1 ratio per pot to make the soil fertile. The experimental studies were done in triplicates. Around 8 to 10 seeds were sown in each pot at a depth of 1.5 cm and watered daily. On the 10th day, priming was done and only five plants were retained in each pot to facilitate the plant growth to its full potential.

Foliar Application of Homobrassinolide (HBL): Homobrassinolide (HBL) was exogenously applied in 3 different concentrations viz., 0.5 μ M, 1.0 μ M and 2.0 μ M. as foliar spray. Three replicates were maintained for each concentration of HBL. Control plants were also maintained in triplicates which were sprayed with distilled water. The pots were placed in open environment and the mustard plants were grown under natural day length. The three different concentrations of HBL were exogenously applied to the plants as foliar spray and the spraying was done in the early hours of the day by using sprayers. The HBL was treated three times to the mustard plants viz., on the 35th, 40th and 45th day after sowing.

Length of Shoot and Root: The pots were adequately watered and the plants were gently removed. All necessary caution was taken to see that the root system was intact. The shoot and root parts were washed with tap water (twice). The water adhering the shoot and the root parts were removed with the help of blotting paper. The shoot and root length was measured on 35th, 45th, 55th and 65th days with using a meter scale and their values were expressed in centimeters.

Fresh Weight of Shoot and Root: After measuring the length, the fresh weights of the shoots and roots were recorded on 55th and 65th days. A meter balance was used for this purpose. The shoot and root fresh weights were expressed in grams.

Dry Weight of Shoot and Root: The shoot and root were dried in the oven at 110°C for 24 hours and their dry weights were recorded on 55th and 65th days. The dry weights were expressed in terms of grams.

Diameter of Fresh Stem and Root: The diameter of fresh stem and root were recorded on 65th day. A screw gage was used for this purpose. The fresh stem and root diameters were expressed in centimeters.

Diameter of Dry Stem and Root: The stem was dried in the oven at 110°C for 24 hours and the diameter of dry stem was recorded on 65th day. A screw gage was used for this purpose. The diameter of the dry stem and root were expressed in centimeters.

Foliage of Mustard Plant: The foliage of the mustard plants grown in semi-arid tropics of Nizamabad was recorded in

terms of number of leaves per plant on 35th, 45th, 55th and 65th day.

Leaf Area of Plant: The leaf area per plant was determined by estimating in on the 55th day after sowing following the formula of Carleton Foote (1965) which is given below:

Leaf area (cm²) = maximum leaf length \times maximum leaf width \times 0.75

(Where, 0.75 is the Correction factor)

The leaf area was multiplied by total number of leaves to calculate total leaf area per plant. The leaf area was recorded on 35th, 45th, 55th and 65th day.

RESULTS

Shoot Length of mustard plant: The effect of HBL on the shoot length of mustard plants are shown in Figure -1. All the treatments of HBL substantially increased the shoot length of mustard plants grown in semi-arid tropics of Nizamabad over the untreated control plants. 2.0 μ M HBL conc. caused maximum increase of 39.21 % followed by 1.0 μ M conc. of HBL which caused an increase of 32.35 % and 0.5 μ M conc. of HBL which caused an increase of 10.78 % over controls on 35th day. 0.5 μ M HBL conc. caused maximum increase of 56.43 % followed by 1.0 μ M conc. of HBL which caused an increase of 48.78 % and 2.0 μ M conc. of HBL which caused an increase of 45.45 % over controls on 45th day. 0.5 μ M HBL conc. caused maximum increase of 90.12 % followed by 1.0 μ M conc. of HBL which caused an increase of 75.92 % and 2.0 μ M conc. of HBL which caused an increase of 46.91 % over controls on 55th day. 2.0 μ M HBL conc. caused maximum increase of 75.5 % followed by 1.0 μ M conc. of HBL which caused an increase of 68.5 % and 0.5 μ M conc. of HBL which caused an increase of 60.16 % over controls on 65th day.

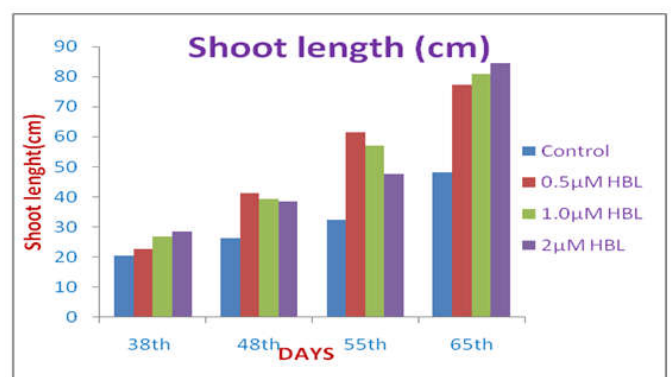


Figure 1. Effect of homobrassinolide (HBL) on the shoot length of mustard plant

Root Length of mustard plant: All the treatments of HBL substantially increased the root length of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants that were recorded on 35th, 45th, 55th and 65th days are shown in Table – 1. 2.0 μ M HBL conc. caused maximum increase of 9.14 % followed by 1.0 μ M conc. of HBL which caused an increase of 6.3 % and 0.5 μ M conc. of HBL which caused an increase of 3.15 % over controls on 35th day. 1.0 μ M HBL conc. caused maximum increase of 11.49 % followed by equal increase of 10.34 % at 0.5 μ M and 2.0 μ M conc. of HBL which caused an over controls on 45th day. 0.5 μ M HBL

conc. caused maximum increase of 24.94 % followed by 2.0 μ M conc. of HBL which caused an increase of 17.23 % and 1.0 μ M conc. of HBL which caused an increase of 13.94 % over controls on 55th day. 2.0 μ M HBL conc. caused maximum increase of 105.3 % followed by 1.0 μ M conc. of HBL which caused an increase of 40 % and 0.5 μ M conc. of HBL which caused an increase of 34.51 % over controls on 65th day.

Table 1. Effect of homobrassinolide (HBL) on the shoot length of mustard plant

Root length(cm)				
Day	35th	45th	55th	65th
Control	6.34 \pm 0.199	8.7 \pm 0.489	8.82 \pm 0.452	11.3 \pm 0.7
0.5 μ M HBL	6.54 \pm 0.235	9.6 \pm 0.244	11.02 \pm 0.342	15.2 \pm 0.583
1.0 μ M HBL	6.74 \pm 0.248	9.7 \pm 0.3	10.5 \pm 0.327	15.82 \pm 0.37 7
2 μ M HBL	6.92 \pm 0.292	9.6 \pm 0.4	10.34 \pm 0.218	23.2 \pm 0.583

The values are mean +S.E (n=5)

Shoot fresh weight mustard plant on 55th day: The effect of HBL on the shoot fresh weight of mustard plants recorded on the 55th day is shown in Table - 2. All the treatments of HBL substantially increased the shoot fresh weight of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants which were recorded on 55th day. 0.5 μ M HBL conc. caused maximum increase of 186.37 % followed by 1.0 μ M conc. of HBL which caused an increase of 143.88 % and 2.0 μ M conc. of HBL which caused an increase of 97.13 % over controls on 55th day.

Shoot dry weight of mustard plant on 55th day: The effect of HBL on the shoot dry weight of mustard plants recorded on the 55th day is shown in Table - 2. All the treatments of HBL substantially increased the shoot dry weight of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants that were recorded on 55th day. 0.5 μ M HBL conc. caused maximum increase of 156.05 % followed by 1.0 μ M conc. of HBL which caused an increase of 108.28 % and 2.0 μ M conc. of HBL which caused an increase of 80.89 % over controls on 55th day.

Table 2. Effect of homobrassinolide (HBL) on the shoot fresh and dry weight of mustard plant on 55th day

Shoot weight (gm/fr.wt.)* on 55 th day		
	Shoot fresh weight (g)	Shoot dry weight (g)
Control	2.79 \pm 0.442	1.57 \pm 0.28
0.5 μ M HBL	7.99 \pm 1.377	4.02 \pm 0.706
1.0 μ M HBL	6.78 \pm 0.113	3.27 \pm 0.115
2 μ M HBL	5.50 \pm 0.283	2.84 \pm 0.174

*Values are mean \pm S.E

Shoot fresh weight of mustard plant on 65th day: The effect of HBL on the shoot fresh weights of mustard plants recorded on the 65th day is shown in Figure - 2. All the treatments of HBL substantially increased the shoot fresh weight of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants which were recorded on 65th day. 0.5 μ M HBL conc. caused maximum increase of 156.05 % followed by 1.0 μ M conc. of HBL which caused an increase of 108.28 % and 2.0 μ M conc. of HBL which caused an increase of 80.89 % over controls on 65th day.

Shoot dry weight of mustard plant on 65th day: The effect of HBL on the shoot dry weights of mustard plants recorded on the 65th day is shown in Figure - 2. All the treatments of HBL substantially increased the shoot dry weight of mustard plant grown in semi-arid tropics of Nizamabad over the untreated

control plants that were recorded on 65th day. 0.5 μ M HBL conc. caused maximum increase of 115.42 % followed by 1.0 μ M conc. of HBL which caused an increase of 75.75 % and 2.0 μ M conc. of HBL which caused an increase of 90.63 % over controls on 65th day.

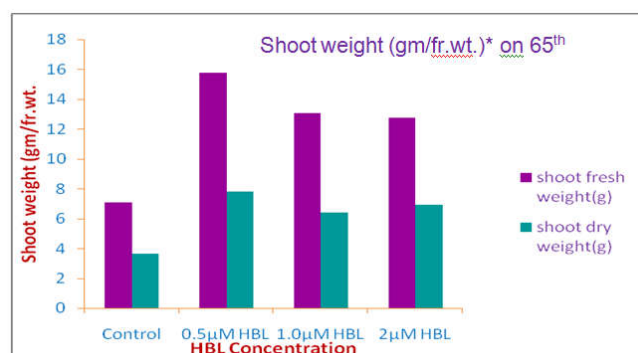


Figure 2. Effect of homobrassinolide (HBL) on the shoot weight of mustard plant on 65th day

Root fresh weight of mustard plant on 55th day: The effect of HBL on the root fresh weights of mustard plants recorded on the 55th day is shown in Table - 3. All the treatments of HBL substantially increased the fresh root weight of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants that were recorded on 55th day. 0.5 μ M HBL conc. caused maximum increase of 175.6 % followed by 1.0 μ M conc. of HBL which caused an increase of 100 % and 2.0 μ M conc. of HBL which caused an increase of 87.8 % over controls on 55th day.

Root dry weight of mustard plant on 55th day: The effect of HBL on the root fresh weights of mustard plants recorded on the 55th day is shown in Table - 3. All the treatments of HBL substantially increased the dry root weight of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants that were recorded on 55th day. 0.5 μ M HBL conc. caused maximum increase of 185 % followed by 1.0 μ M conc. of HBL which caused an increase of 120 % and 2.0 μ M conc. of HBL which caused an increase of 115 % over controls on 55th day.

Table 3. Effect of homobrassinolide (HBL) on the root fresh and dry weight of mustard plant on 55th day

Root weight (gm/fr.wt.)*on55th day		
	Root fresh weight(g)	Root dry weight(g)
Control	0.41 \pm 0.12	0.20 \pm 0.06
0.5 μ M HBL	1.13 \pm 0.423	0.57 \pm 0.217
1.0 μ M HBL	0.82 \pm 0.005	0.44 \pm 0.017
2 μ M HBL	0.77 \pm 0.035	0.43 \pm 0.038

The values are mean +S.E (n=3)

Root fresh weight of mustard plants on 65th day: The effect of HBL on the root fresh weights of mustard plants recorded on the 65th day is shown in Figure - 3. All the treatments of HBL substantially increased the fresh root weight of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants that were recorded on 65th day. 0.5 μ M HBL conc. caused maximum increase of 331 % followed by 1.0 μ M conc. of HBL which caused an increase of 300 % and 2.0 μ M conc. of HBL which caused an increase of 173.77 % over controls on 65th day.

Root dry weight of mustard plants on 65th day: The effect of HBL on the Root dry weights of mustard plants recorded on

the 65th day are shown in Figure - 3. All the treatments of HBL substantially increased the dry root weight of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants that were recorded on 65th day. 0.5 μ M HBL conc. caused maximum increase of 343 % followed by 2.0 μ M conc. of HBL which caused an increase of 313 % and 1.0 μ M conc. of HBL which caused an increase of 310 % over controls on 65th day.

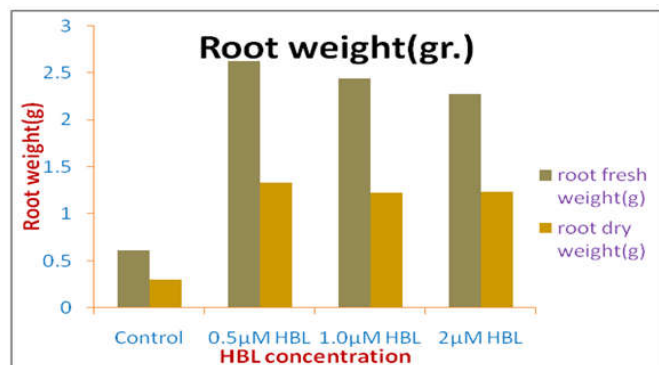


Figure 3. Effect of homobrassinolide (HBL) on Root fresh and dry weight of mustard plant on 65th day

Diameter of the stem (fresh) of mustard plant: The effect of HBL on the stem fresh diameter of mustard plants recorded on the 65th day is shown in Table - 4. All the treatments of HBL substantially increased the diameter of the fresh stem of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants which were recorded on 65th day. 2.0 μ M HBL conc. caused maximum increase of 102.53 % followed by 1.0 μ M conc. of HBL which caused an increase of 68.25 % and 0.5 μ M conc. of HBL which caused an increase of 66.22 % over controls on 65th day.

Diameter of the stem (dry) of mustard plant: The effect of HBL on the stem dry diameter of mustard plants recorded on the 65th day are shown in Table - 4. All the treatments of HBL substantially increased the diameter of the dry stem of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants that were recorded on 65th day. 2.0 μ M HBL conc. caused maximum increase of 130.18 % followed by 1.0 μ M conc. of HBL which caused an increase of 102.44 % and 0.5 μ M conc. of HBL which caused an increase of 71.00 % over controls on 65th day.

Table 4. Effect of homobrassinolide (HBL) on the diameter of the stem of mustard plant on 65th day

Diameter of the Stem (cm)* on 65 th day		
	Diameter of the stem (Fresh)	Diameter of the stem (dry)
Control	4.737 \pm 0.16	3.194 \pm 0.19
0.5 μ M HBL	7.874 \pm 0.30	5.462 \pm 0.24
1.0 μ M HBL	7.97 \pm 0.23	6.466 \pm 0.20
2 μ M HBL	9.594 \pm 0.24	7.352 \pm 0.27

*Values are mean +S.E

Diameter of the root (fresh) of mustard plant

The effect of HBL on the root fresh diameter of mustard plants recorded on the 65th day is shown in Figure - 4. All the treatments of HBL substantially increased the diameter of fresh root top of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants that were recorded on 65th day. 2.0 μ M HBL conc. caused maximum increase of 102.56 % followed by 1.0 μ M conc. of HBL which

caused an increase of 85.38 % and 0.5 μ M conc. of HBL which caused an increase of 59.74 % over controls on 65th day.

Diameter of the root (dry) of mustard plant

The effect of HBL on the root dry diameter of mustard plants recorded on the 65th day is shown in Figure -4. All the treatments of HBL substantially increased the diameter of dry root top of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants that were recorded on 65th day. 2.0 μ M HBL conc. caused maximum increase of 122.51 % followed by 1.0 μ M conc. of HBL which caused an increase of 88.41 % and 1.0 μ M conc. of HBL which caused an increase of 75.49 % over controls on 65th day.

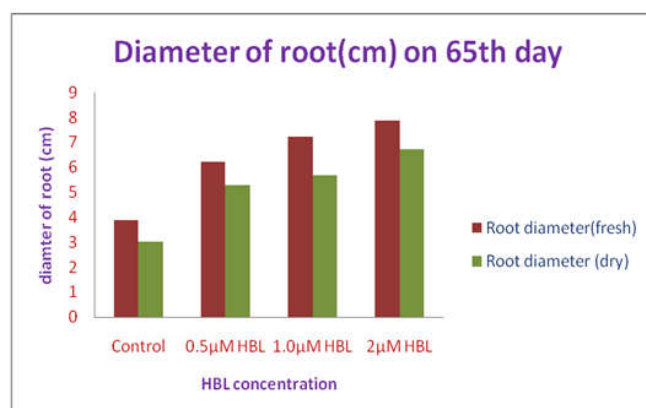


Figure 4. Effect of homobrassinolide HBL on the diameter of the root (dry) of mustard plant on 65th day

Foliage of mustard Plant: All the treatments of HBL substantially increased the no. of leaves of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control plants that were recorded on 35th, 45th, 55th and 65th day are shown in Table - 5. 0.5 μ M HBL conc. caused maximum increase of 21.42 % followed by 2.0 μ M conc. of HBL which caused an increase of 10.71 % and 1.0 μ M conc. of HBL which caused an increase of 7.14 % over controls on 35th day. 0.5 μ M HBL conc. caused maximum increase of 45.83 % followed by 1.0 μ M conc. of HBL which caused an increase of 33.33 % and 2.0 μ M conc. of HBL which caused an increase of 28.57 % over controls on 45th day. 0.5 μ M HBL conc. caused maximum increase of 48.83 % followed by 1.0 μ M conc. of HBL which caused an increase of 41.86 % and 2.0 μ M conc. of HBL which caused an increase of 32.55 % over controls on 55th day. 0.5 μ M HBL conc. caused maximum increase of 95.55 % followed by 2.0 μ M conc. of HBL which caused an increase of 93.33 % and 1.0 μ M conc. of HBL which caused an increase of 35.5 % over controls on 65th day.

Table 5. Effect of homobrassinolide (HBL) on leaves of mustard plant

Mustard leaves					
Day	35 th day	45 th day	55 th day	65 th day	
Control	5.6 \pm 0.24	8.4 \pm 0.67	8.6 \pm 0.67	9 \pm 0.83	
0.5 μ M HBL	6.8 \pm 0.58	12.2 \pm 1.49	12.8 \pm 0.37	17.6 \pm 0.50	
1.0 μ M HBL	6 \pm 0.31	11.2 \pm 0.91	12.2 \pm 0.73	12.2 \pm 0.37	
2 μ M HBL	6.2 \pm 0.2	10.8 \pm 0.73	11.4 \pm 1.20	17.4 \pm 0.50	

The values are mean +S.E (n=5)

Leaf area of Mustard Plant: All the treatments of HBL substantially increased the leaf area of mustard plant grown in semi-arid tropics of Nizamabad over the untreated control

plants that were recorded on 35th, 45th, 55th and 65th day are shown in Figure - 5. Leaf growth of mustard leaves in square centimeters (sq.cm)². 0.5 μ M HBL conc. caused maximum increase of 381.631 % followed by 2.0 μ M conc. of HBL which caused an increase of 221.95 % and 1.0 μ M conc. of HBL which caused an increase of 116.43 % over controls on 35th day. At 1.0 μ M and 2.0 μ M HBL conc. caused maximum increase of 230.13 % followed by 0.5 μ M conc. of HBL which caused an increase of 171.55 % over controls on 45th day. 0.5 μ M HBL conc. caused maximum increase of 267.47% followed by 1.0 μ M conc. of HBL which caused an increase of 216.52% and 2.0 μ M conc. of HBL which caused an increase of 201.35% over controls on 55th day. 0.5 μ M HBL conc. caused maximum increase of 225.16 % followed by 2.0 μ M conc. of HBL which caused an increase of 179.41 % and 1.0 μ M conc. of HBL which caused an increase of 97.71 % over controls on 65th day.

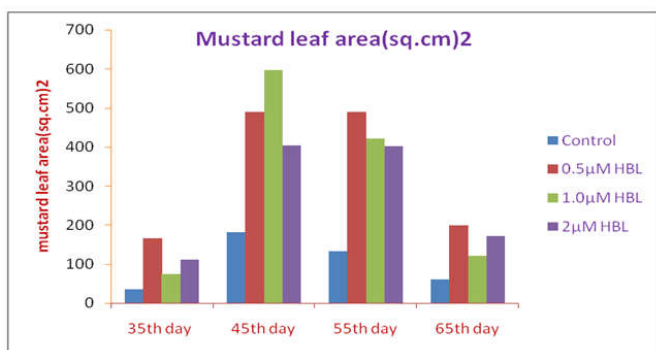


Figure 5. Effect of homobrassinolide (HBL) on leaf area of mustard plant

DISCUSSION

It is a well-established fact that BRs are a new group of PGRs which play a positive role in the growth and development of plants. BRs increased the height of two field-grown inbred lines of maize (*Zea mays* L.) during the vegetative and early reproductive phases of plant development during the early weeks after their application (Holla *et al.*, 2010).

Shoot growth: Seed treatment and foliar application of BL at 0.05, 0.1 & 0.2 ppm resulted in significant increase in growth of tomato (*Lycopersicon esculentum* L.) in terms of length, fresh and dry weight of shoots (Nafie and El-Khallal, 2002). Foliar application of BRs as foliar spray enhanced the growth of ground nut plants (Vardhini and Rao, 1998) and tomato plants (Vardhini and Rao, 2003). Supplementation of BL improved the dry-weight and growth in mulberry shoots (Kuno, 1997). Supplementation of 24-epiBL to the media resulted in stem elongation of sweet pepper (Franck-Duchenne *et al.*, 1998). Kim *et al.* (2008) studied that supplementation of BL to the culture media influences the regeneration of adventitious shoots from cultured leaf discs of tobacco. 28-HomoBL and 24-epiBL improved the growth parameters in *Lycopersicon esculentum* (cv. K-21) sampled at 45 (24 h after spray) and 60 days after sowing (Hayat *et al.*, 2011). Application of BRs enhanced the growth in terms of plant height and dry weight of shoots of *Plectranthus forskohlii*/coleus (Swamy and Rao, 2011) and *Pelargonium graveolens* (L.) Herit. (Swamy and Rao, 2009). Exogenous application of BL resulted in improved growth and anatomical characteristics for stems of dwarf pear *in vitro* conditions (Chen *et al.*, 2014). Even in the present study, application of HBL significantly

increased the shoot growth in mustard plants grown in the semi-arid soils of Nizamabad.

Root Growth: 24-EpiBL played a distinctive role on the growth of onion (*Allium cepa*) root tips (Howell *et al.*, 2007). 24-EpiBL played a pivotal role in the development of excised roots of tomato grown *in vitro* (Roddick *et al.*, 1993). BRs triggered growth promotion of apical meristems in potato tubers (Meudt *et al.*, 1983). Supplementation of BRs resulted in increased root nodulation in French bean (Upreti and Murti, 2004) and also improvement in root epidermal cells (Cheng *et al.*, 2014). BRs increased the root nodulation and nitrogenase activity in ground nut plants (Vardhini & Rao, 1999) and soya bean plants (Miao *et al.*, 2013). Vardhini *et al.* (2012) reported that application of BRs increased the qualitative growth of radish in terms of root fresh weight, root dry weight, oxalic acid, ascorbic acid, folic acid and niacin. Application of 24-EpiBL (Platonova & Korableva, 1994) and BL (Korableva *et al.*, 2002) promoted the growth of apical meristem of potato tubers. (2S, 23S)-HomoBL enhanced the rooting capacity and survival of adult Norway spruce cuttings (Rönsch *et al.*, 1993). BL increased the growth and ginsenoside content of *Panax quinquefolium* hairy root (Zhou *et al.*, 2003). Treatment with two synthetic BRs improved the *in vitro* growth of *Yucca filamentosa*, *Dioscorea rotundata* and *Ananas comosus* (Bieberach *et al.*, 2000). Hayat *et al.* (2011) reported that 28-homoBL and 24-epiBL increased the growth of *Lycopersicon esculentum*. Imbibitions of 24-epiBL to pea (*Pisum sativum* L.) cv. Climax seeds subjected to sodium chloride stress exhibited increased germination, embryo axis length and most of the aspects of shoot and root growth at seedling stage (Shahid *et al.*, 2011). Earlier studies clearly emphasized that external supplementation/application of BRs improved plant growth in the case of wheat (Sairam, 1994) and groundnut (Vardhini and Rao, 1998) which is in tune with the present study where foliar application of HBL substantially increased the root growth of mustard plants grown in semi-arid tropics of Nizamabad.

Foliar growth: The enhanced shoot and root growth of HBL treated mustard plants was associated with increased foliar growth. Application of BRs resulted in proliferation of leaf cells (Nakaya *et al.*, 2002) of *Arabidopsis thaliana*, leaf expansion in *Solanum lycopersicon* (Zhiponova *et al.*, 2013) and improvement of leaf nutrition in *Camellia oleifera* (Zhou *et al.*, 2013) was observed. Further, regeneration of adventitious shoots from cultured leaf discs of tobacco (Kim *et al.*, 2008) was also reported. Arteca and Arteca (2001) also reported that BRs not only induce exaggerated growth in hydroponically grown *Arabidopsis thaliana*, but also control the proliferation of its leaf cells (Nakaya *et al.*, 2002). Schlaghaufer & Arteca (1985) studied that BRs induced epinasty in tomato (*Lycopersicon esculentum* cultivar Heinz 1350) plants. Oh and Clouse (1998) and Ho (2003) reported that BL accelerated the rate of cell division in isolated leaf protoplasts of *Petunia hybrida*. Application of 24-epiBL and 28-homoBL enhanced the growth in terms of leaf number, leaf area, and the dry weight of leaves of coleus (Swamy and Rao, 2011). BL improved the physiological characteristics of *Brassica oleracea* var. *italica* leaves (Wang and Yang, 2009). Exogenous application of BL resulted in improved growth and anatomical characteristics for leaves of dwarf pear *in vitro* conditions (Chen *et al.*, 2014). The present study reveals that application of HBL on mustard plants as foliar spray promoted the shoot, root and foliar growth of mustard plants grown in semi-arid soils of Nizamabad. The soils of Nizamabad are

saline and dry in nature inhibiting the growth of plants. BRs have the ability to promote growth of plant under stressful conditions. The present study reveals a new insight that application of HBL overcame the negative effect of the semi-arid conditions of the soil (reflected in the control plants) and promoted the shoot, root and foliar growth (reflected in the HBL-treated plants) of mustard.

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