International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(5): 1278-1282

Received: 11-07-2019
Accepted: 15-08-2019

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Growth and yield of barley (*Hordeum vulgare* L.) varieties as influenced by application of plant growth regulators

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Abstract
A field experiment entitled "Growth and yield of Barley (*Hordeum vulgare* L.) varieties as influenced by application of Plant growth regulators" was conducted during the *rabi* season of 2017-18 at research farm of Wheat & Barley Section, Dept. of Genetics and Plant Breeding, Chaudhary Charan Singh, Haryana Agricultural University, Hisar. The experiment comprised of two varieties (BH 946 & DWRUB 52) in main plot and application of PGRs alone or in combination *viz.* T_1: Folicur (0.1%) at GS_{50}, T_2: Folicur (0.1%) at GS_{80}, T_3: Cycocel @ 1.25 l ha^{-1} at GS_{31}, T_4: Ethephon @ 0.5 l ha^{-1} at GS_{40} and T_5: Cycocel @ 1.25 l ha^{-1} at GS_{31}+ Ethephon @ 0.5 l ha^{-1} at GS_{40} in sub plot under Factorial RBD design with three replications. Variety BH-946 exhibited significantly better growth parameters *viz.,* plant height, dry matter accumulation $metre^{-1}$ row length and leaf area index (LAI) in comparison with DWRUB 52. Whereas, the grain yield and harvest index of 51.3 q $ha^{-1}$and 39.2%, respectively were recorded maximum in DWRUB 52. Application of Cycocel and Ethephon, alone or in combination significantly reduced plant height and increased dry matter accumulation $metre^{-1}$ row length, leaf area index (LAI) and total tillers $metre^{-1}$ row length. The highest grain yield (52.5 q ha^{-1}) and harvest index (37.7 %) were recorded under Cycocel + Ethephon.

Keywords: Barley varieties, PGRs, plant height, dry matter accumulation, LAI and yield

Introduction

Barley (*Hordeum vulgare* L.) is a versatile cereal grain grown worldwide and belongs to the family Poaceae and ranks fourth in acreage and production after wheat, rice and maize. It is a *rabi* season, fast growing, annual grain crop that could be used for green fodder purpose as well as cover crop to improve soil fertility (Ghanbari *et al*., 2012) [12]. In India, it is primarily grown for human consumption and it can replace wheat as the dominant crop due to its tolerance to drought and salinity. Barley grain is also valued for its cooling effect on the human body for easy digestion.

The barley grains make a palatable and nutritious livestock feed and can also be used for making fodder sprouts, besides this the straw is also used as dry fodder, its green fodder either directly fed to the animals or used for making hay and silage. Grain used for livestock or human feed tend to have higher protein content. Besides these conventional uses, it is also an important industrial crop because it is used as raw material for making beer and whisky. Malt is the second largest use of barley and malting barley is grown as cash crop in many developing and developed countries including India. In India, about 75% of barley is used as feed, 20% for malt purpose and remaining 5% for food purposes and its byproduct dry straw is largely used to feed livestock. The utilization of barley for malting has picked up recently with an increase in consumption of beer and other malt-based products in many countries including India. The mid-way products of malting find uses in bakery preparations and energy rich foods for human consumption.

In the world, barley crop covers an area of 49.29 m ha with production 147.16 m t and productivity of 2990 kg ha^{-1} during 2016-17 (Anonymous, 2018) [3]. Barley's area, production and productivity of India is 5.89 m ha, 14.37 m t and 2439 kg ha^{-1}, respectively. In India, Eastern Uttar Pradesh and North-Western districts of Bihar comprise the major barley growing area. In addition to these areas, Southern Uttar Pradesh, Northern Madhya Pradesh, North-Eastern and Southern districts of Rajasthan and Haryana, and hills of Uttarakhand and Himachal Pradesh constitute important producing regions in respect of barley production. In

Haryana, Barley is grown mainly in the South-Western zone with an area of is 2.90 m ha with production 9.90 m t and productivity of 3414 kg ha^{-1} (Anonymous, 2016) [1].

Plant growth regulators (PGRs) are widely used in contemporary agriculture to have beneficial effect on plant growth and yield (Ashraf *et al*., 2011) [2]. PGRs are exogenously applied chemical substances which can alter the growth and developmental processes, leading to increased yield, improved grain quality or facilitated harvesting (Espindula *et al*., 2009) [11]. Growth retardants reduce plant lodging and improve plant architecture, thereby increasing efficiency in capturing solar radiation and other environmental resources (Zagonel and Fernandes, 2007) [22]. These effects can change assimilate partitioning, improves seed filling and consequently the physiological quality of the seeds. The most widely evidenced effect in the scientific literature for PGRs is the reduction of plant height when PGRs are applied at early stem elongation in cereals (Berry *et al*., 2004) [6]. Shorter plant height improves crop resistance to lodging and can improve harvestability and possibly grain quality. PGRs application have been known to alter tiller and spikelet production as well as survival through changes that resemble day-length responses (Davies, 2010) [10].

Amongst PGRs, Ethephon and Chlormequat chloride have been found effective in decreasing plant height and reducing lodging incidence in wheat (Crook and Ennos, 1995) [8]. However, the effectiveness of PGRs in controlling lodging depends on many factors including variety, type of growth regulator, its application rate, crop growth stages at the time of application and its dose.

Folicur or Tebuconazole is a systemic triazole fungicide. Triazoles (tebuconazole) registered for their fungicidal activity in cereals also exhibit growth retardation activity (Kruse and Verreet, 2005) [14]. However, these compounds also cause transformations in plant growth and development primarily by reducing gibberellin biosynthesis. Applications of Folicur also results in greening effect on the crop foliage and thereby increase in grain yield. Keeping these facts in mind, the experiment was conducted to observe the effect of PGRs on growth and yield of barley crop.

Materials and Methods

The experiment was conducted during *rabi* season of 2017-18 at research farm of Wheat and Barley Section, Department of Genetics & Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana (India), situated at 29°10' N latitude and 75°46' E longitude at an elevation of 215.2 m above mean sea level. The mean weekly meteorological data during crop seasons of 2017-18 recorded at meteorological observatory located at Chaudhary Charan Singh Haryana Agricultural University, Hisar are given in Figure 1. An analysis of weather parameters reveal that maximum and minimum temperature ranged between 18.0 to 33.4 °C and 2.6 to 12.6 ºC during *rabi* 2017-18, respectively. Mean weekly maximum and minimum relative humidity ranged between 78 to 100 per cent and 25 to 66 per cent, respectively. Total rainfall received during the crop season was 2.3 mm. Before sowing of the experiment, soil samples were collected from 0-15 cm depth and analysed for mechanical, physical and chemical properties. The texture of the surface soil of the experimental field was sandy loam, containing 61.6% sand, 16.8% silt and 21.8% clay. It was slightly alkaline (pH 8.2) in nature, the organic carbon content was 0.38% and the soil was low in available N (181 kg ha^{-1}), medium in available P (14.2 kg ha^{-1}) & high in available K (375 kg ha^{-1}). The experiment comprised of two varieties (BH 946 & DWRUB 52) in main plot and application of PGRs alone or in combination {T_1: Folicur (0.1%) at GS_{50}, T_2: Folicur (0.1%) at GS_{80}, T_3: Cycocel @ 1.25 l ha^{-1} at GS_{31}, T_4: Ethephon @ 0.5 l ha^{-1} at GS_{40} and T_5: Cycocel @ 1.25 l ha^{-1} at GS_{31}+ Ethephon @ 0.5 l ha^{-1} at GS_{40}} in sub plot under Factorial RBD design with three replications. The nitrogen @ 60 kg ha^{-1}was applied through urea after adjusting the nitrogen supplied through Diammonium phosphate (applied for 30 kg P2O5 ha^{-1}). Half of nitrogen and full dose of phosphorous was applied as basal and remaining nitrogen were given at Ist irrigation. The experiment was sown on 18th Nov. 2017. Observations on growth parameters *viz.*, plant height, dry matter accumulation and total tillers were recorded from each plot at different stages *viz.*, at 30, 60, 90, 120 Days after sowing (DAS) and at maturity. The grain yield, straw yield and biological yield were recorded at harvest. Harvest index was calculated for each plot by using following formula:

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Data were analyzed by using OPSTAT software available at CCS Haryana Agricultural University website (Sheoran *et. al*., 1998) [20]. The results are presented at five per cent level of significance (P=0.05) for making comparison between treatments.

Results and Discussion

Data related to plant height at various stages of plant growth is presented in Table 1. The plant height increased with the advancement of crop growth up to maturity of the crop. The rate of increase in plant height was maximum between 60-90 DAS as compared to 0-30 and 30-60 DAS and thereafter, it increased marginally upto maturity of the crop. Further, it was observed that the plant height in variety BH 946 was significantly higher than the variety DWRUB 52 at all the stages of crop growth. Application of PGRs had brought out significant effect on plant height at all stages of crop growth except at 30 DAS. The minimum plant height of 53.3, 82.5, 87.6 and 87.9 cm was recorded with treatment T_5 at 60, 90, 120 DAS and at maturity, respectively followed by T_3 (55.2, 84.5, 89.4 and 89.7 respectively) and T_4 (57.3, 86.1, 90.6 and 90.9 cm, respectively). The significant difference in plant height between the barley varieties was also reported by Todar Mal (2013) [21]. Plant height was also significantly decreased by 8.8%, 7.5%, 7.6%, 7.8% with the application of Cycocel + Ethephon combination (T_5) over the Folicur applied treatment (T_1) at 60 DAS, 90 DAS, 120 DAS and at maturity. Growth retardants induced reduction in stem elongation in barley and wheat, which is attributed to either reduction in gibberellic acid (GA) synthesis or increase in ethylene synthesis (Gianfagna, 1995) [13] and Rajala (2004) [18].

The data pertaining to dry matter accumulation (Table 2) indicated that dry matter accumulation metre^{-1} row length at various growth stages increased progressively from vegetative upto harvest stage. The rate of increase in dry matter accumulation was highest between 30 to 60 DAS and thereafter, the increase was at a decreasing rate upto maturity. Among the varieties, BH 946 accumulated 1.8, 5.1, 15.4, 48 and 52.4 g more dry matter at 30, 60, 90, 120 DAS and at maturity than DWRUB 52, respectively. The differential dry matter accumulation among varieties were also reported by Sharma *et al.* (2007) [19]. The dry matter accumulation metre^{-1} row length increased significantly with the PGR treatments at all crop growth stages. However, the maximum dry matter accumulation metre^{-1} row length was recorded with T_5 which was statistically at par with T_3 but significantly higher over T_4, T_1 and T_2 at all the crop growth stages. At maturity, the dry matter accumulation in T_5 treatment was 1.4%, 3.7% and 3.9% higher over T_4, T_1 and T_2 treatments, respectively, since decreasing plant height is one of the ways of increasing the stem diameter and number of tillers and more production of dry matter (Miranzadeh *et al*, 2011) [15].

Perusal of the data from Table 3 revealed that LAI increased with the advancement of crop age and reaching peak at 90 DAS and it decreased tremendously thereafter at 120 DAS because of leaf senescence and tiller mortality at later growth stages. The LAI was significantly higher with the variety BH 946 (0.16-3.57) at all the stages as compared to DWRUB 52 (0.11-3.30). The PGRs also had significant effect on LAI at 60 and 90 DAS. The maximum LAI of 2.56 and 3.51 were recorded in the treatment T_5 at 60 and 90 DAS which was statistically at par with T_3, T_4 whereas, minimum LAI was recorded with T_2 at both the stages. At 120 DAS, LAI was not influenced significantly by any of the PGRs treatment. The decrease in plant height resulted in excess of photo-assimilates for growth of alternative sink *i.e.* increase in leaf area which will ultimately increase LAI. The results of present study are in conformation with the results of Miranzadeh *et al*. (2011) [15], Pirasteh Anosheh *et al*. (2012) [16]. The maximum increase in number of tillers was observed from 30 to 60 DAS and thereafter, they increased marginally upto 90 DAS.

Significantly higher total tillers metre^{-1} row length (Table 4) were recorded with DWRUB 52 (61.0, 135.5, 145.4, 129.3, 122.7) as compared to BH 946 (55.8, 130.3, 139.6, 102.7, 93.1) at 30, 60, 90, 120 DAS and at maturity, respectively. Total tillers metre^{-1} row length were significantly influenced by the application of different plant growth regulators alone or in combination. Maximum number of total tillers per metre row length were recorded in the T_5 treatment which remained statistically at par with T_3 but significantly higher over T_1 and T_2 at all the stages except at 30 DAS. Rajala (2004) [18] hypothesized that PGRs induced inhibition of shoot elongation and provided excess photo-assimilates for growth of alternative sink *i.e.* for growth of tiller.

The grain yield of barley varieties as influenced by different PGRs is given in Table 5. DWRUB 52 recorded significantly higher grain yield (51.3 q ha^{-1}) than BH 946 (48.5 q ha^{-1}). The grain yield was recorded 5.8% higher in DWRUB 52 variety over the BH 946. Variation in grain yield of barley varieties was also reported by Chakrawarty and Kushwaha (2007) [7]. Among PGR treatments, grain yield increased significantly with the application of Cycocel alone or in combination with Ethephon as compared to Folicur applied treatments at different growth stages. The highest grain yield of 52.5 q ha^{-1} was recorded with T_5 treatment, which was found statistically at par with T_3 (51.1 q ha^{-1}), but significantly higher than T_4, T_1 and T_2 with the values of 50.1, 48.0, 47.7 q ha^{-1}, respectively. The grain yield of T_5 was 4.8, 9.4 and 10.1 % higher over the T_4, T_1 and T_2 treatments, respectively. Higher grain yield was attributed to its reduction in plant height at tillering which lead to higher tiller survival and enhances fertile tillers, which resulted in greater yield in barley. Corroborative results were recorded by Dastan *et al.* (2011) [9] and Bahrami *et al.* (2014b) [5].

BH 946 recorded maximum straw and biological yield which was significantly higher than DWRUB 52. The maximum yield was recorded with the application of Cycocel + Ethephon combination (T_5) followed by Cycocel (T_3), but it was significantly higher over the other treatments. This is because of the fact that Cycocel + Ethephon or Cycocel causes reduction in plant height, thereby provides excess photo-assimilates for increasing stem girth, leaf area, total number of branches in the plant etc. These findings are in substantiate with the results reported by Bahrami *et al.* (2014a) [4] and Rajala and Peltonen-Sainio (2001) [17]. The variety DWRUB 52 recorded significantly higher value of harvest index which was 4% higher as compared to variety BH 946. The plant growth regulators did not show any significant effect on the harvest index, however, maximum harvest index was observed under Cycocel + Ethephon combination (T_5).

Table 1: Effect of PGRs on plant height of barley varieties

Treatment		**Plant height (cm)**			
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**Maturity**
Varieties					
BH 946	30.3	58.8	88.1	93.1	93.5
DWRUB 52	26.2	54.4	84.1	89.2	89.4
SEm ±	0.5	0.8	0.4	0.4	0.5
CD at 5%	1.5	2.4	1.3	1.3	1.3
PGRs					
T_1-Folicur (0.1%) at GS50	27.7	58.5	89.2	94.8	95.3
T_2-Folicur (0.1%) at GS80	28.3	58.7	88.2	93.3	93.5
T_3-Cycocel @ 1.25 l ha^{-1} at GS_{31}	28.9	55.2	84.5	89.4	89.7
T_4-Ethephon @ 0.5 l ha^{-1} at GS_{40}	28.2	57.3	86.1	90.6	90.9
T_5-Cycocel @ 1.25 l ha^{-1} at GS_{31} + Ethephon @	28.3	53.3	82.5	87.6	87.9
0.5 l ha^{-1} at GS_{40}					
SEm ±	0.8	1.3	0.7	0.7	0.7
CD at 5%	NS	3.8	2.1	2.0	2.1

Table 2: Influence of PGRs on dry matter accumulation of barley varieties

Treatment	Dry matter accumulation metre^{-1} row length (g)					
	30 DAS	**60**	**DAS**	90 **DAS**	**120 DAS**	**Maturity**
Varieties						
BH 946	12.3	52.5		164.2	332.5	338.0
DWRUB 52	10.5	47.4		148.8	284.5	285.6
SEm ±	0.1	0.4		0.4	0.6	0.6
CD at 5%	0.4	1.1		1.1	1.9	1.8
PGRs						
T_1-Folicur (0.1%) at GS_{50}	11.1	45.9		153.6	300.3	306.2
T_2-Folicur (0.1%) at GS80	11.3	47.3		153.6	300.0	305.7
T_3-Cycocel @ 1.25 l ha^{-1} at GS_{31}	11.6	52.1		158.3	314.0	315.6
T_4-Ethephon @ 0.5 l ha^{-1} at GS_{40}	11.4	50.5		157.5	312.0	313.5
T_5-Cycocel @ 1.25 l ha^{-1} at GS_{31} + Ethephon @	11.5	53.8		159.6	316.2	317.8
0.5 l ha^{-1} at GS_{40}						
SEm ±	0.2	0.6		0.6	1.0	0.9
CD at 5%	NS	1.7		1.7	3.0	2.8

Table 3: Periodical changes in leaf area index (LAI) of barley varieties as affected by PGR treatments

Treatment		Leaf area index		
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**
Varieties				
BH 946	1.31	2.71	3.57	0.16
DWRUB 52	1.11	2.28	3.30	0.11
SEm ±	0.01	0.01	0.01	0.003
CD at 5%	0.02	0.02	0.02	0.01
PGRs				
T_1-Folicur (0.1%) at GS_{50}	1.22	2.43	3.38	0.13
T_2-Folicur (0.1%) at GS80	1.21	2.40	3.36	0.13
T_3-Cycocel @ 1.25 l ha^{-1} at GS_{31}	1.20	2.55	3.49	0.14
T_4-Ethephon @ 0.5 l ha^{-1} at GS_{40}	1.21	2.53	3.47	0.14
T_5-Cycocel @ 1.25 l ha^{-1} at GS_{31} + Ethephon @	1.22	2.56	3.51	0.15
0.5 l ha^{-1} at GS_{40}				
SEm ±	0.01	0.01	0.01	0.01
CD at 5%	NS	0.04	0.03	NS

Table 4: Influence of PGRs on total tillers per metre length of barley varieties

Treatment	Total tillers metre^{-1} row length				
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**Maturity**
Varieties					
BH 946	55.8	130.3	139.6	102.7	93.1
DWRUB 52	61.0	135.5	145.4	129.3	122.7
SEm ±	0.4	0.5	0.6	0.5	0.5
CD at 5%	1.3	1.4	1.8	1.6	1.4
PGRs					
T_1-Folicur (0.1%) at GS_{50}	57.8	126.5	135.3	113.3	105.5
T_2-Folicur (0.1%) at GS80	58.4	125.7	135.0	112.8	105.7
T_3-Cycocel @ 1.25 l ha^{-1} at GS_{31}	59.0	137.5	147.7	118.2	109.5
T_4-Ethephon @ 0.5 l ha^{-1} at GS_{40}	57.9	135.8	145.7	116.1	108.0
T_5-Cycocel @ 1.25 l ha^{-1} at GS_{31} + Ethephon @	58.7	139.0	148.7	119.7	110.7
0.5 l ha^{-1} at GS_{40}					
SEm ±	0.7	0.7	0.9	0.9	0.7
CD at 5%	NS	2.2	2.8	2.6	2.2

Table 5: Effect of PGRs on yield and harvest index of barley varieties

Treatment	Grain yield	Straw yield	Biological	Harvest
	(q ha^{-1})	**(q ha^{-1})**	**yield**	**Index**
			(q ha^{-1})	**(%)**
	Varieties			
BH 946	48.5	89.5	138.0	35.2
DWRUB 52	51.3	79.6	130.9	39.2
SEm ±	0.5	0.6	0.8	0.2
CD at 5%	1.4	2.0	2.3	0.7
	PGRs			
T_1-Folicur (0.1%) at GS_{50}	48.0	82.0	129.9	37.0
T_2-Folicur (0.1%) at GS80	47.7	82.3	130.0	36.7

T_3-Cycocel @ 1.25 l ha^{-1} at GS_{31}	51.1	86.4	137.5	37.0
T_4-Ethephon @ 0.5 l ha^{-1} at GS_{40}	50.1	84.3	134.4	37.4
T_5-Cycocel @ 1.25 l ha^{-1} at GS_{31} +	52.5	87.8	140.3	37.7
Ethephon @ 0.5 l ha^{-1} at GS_{40}				
SEm ±	0.8	1.0	1.2	0.4
CD at 5%	2.3	3.0	3.7	NS

Conclusion

On the basis of the results, it can be concluded that variety DWRUB 52 performed better in terms of grain yield followed by BH 946. Among PGRs, Cycocel @ 1.25 l ha^{-1} at GS_{31}+ Ethephon @ 0.5 l ha^{-1} at GS_{40} exhibited better growth attributes and grain yield as compared to other PGRs treatments.

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