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Growth and yield of garlic (*Allium sativum* L) as influenced by clove weight and plant growth regulators

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ABSTRACT

The present investigations were carried out on Agrifound Parvati cultivar of garlic at Pandah experimental farm of Seed Technology and Production Centre, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP during Rabi 2009-10. The experiment was laid out in Randomized Block Design (factorial) with three replications of each treatment combination (clove weight x growth regulator). The observations were recorded on plant height, number of leaves per plant, bolters, biomass yield per plot and bulb yield per plot. Analysis of variance showed significant differences among all the treatment combinations for all the characters under study. Highest bulb yield per plot (3.79 kg) was obtained with the treatment combination W_5 x G_2 (clove weight 3.1-3.5 g x Cycocel 1000 ppm). Moreover clove weight W_5 (3.1-3.5 g) and growth regulator G_2 (Cycocel 1000 ppm) independently as well as in their combination also gave the best results for most of the growth and yield characters. Therefore clove weight W_5 (3.1-3.5 g) in combination with growth regulator G_2 (Cycocel 1000 ppm) can be recommended for commercial cultivation/application after multilocation testing for getting the higher yields in garlic.

Keywords: Cycocel; paclobutrazol; clove weight; garlic

INTRODUCTION

Garlic (*Allium sativum* L) is the most widely used cultivated *Allium* species after onion belonging to the family Amaryllidaceae. It is consumed both fresh as well as in dried form as an important ingredient for flavouring various vegetarian and non-vegetarian dishes. In the Indian sub-continent people use fresh leaves of garlic as salad and a good tasty pickle is also prepared from garlic cloves. Garlic has higher nutritive value as compared to other bulbous crops. It is a rich source of carbohydrates (29%), proteins (6.3%), minerals (0.3%) and essential oils (0.1-0.4 %) and also contains fat, vitamin C and sulphur (Memane et al 2008). Ascorbic

acid content is very high in green garlic. In addition to this garlic has several medicinal values. It has antibacterial (Arora and Kaur 1999), antifungal (Hughes and Lawson 1991), antiviral (Meng et al 1993) and antiprotozol properties (Reuter et al 1996). It is beneficial to cardiovascular and immune system and has antioxidant and anticancer properties (Harris et al 2001). Therefore its reputation as a medicine has increased to the extent that garlic oil capsules are now marketed through pharmacies and health food stores (Rahim and Fordham 1994).

Garlic productivity in India is comparatively low as compared to world. So in the recent years due attention has been given to improve the plant growth and yield with the application of plant growth regulators as they modify plant characters like plant height, number of leaves per plant, number and size of cloves and bulbs, biomass yield, net bulb yield etc by influencing the physiological processes within the plant which ultimately affect the yield and quality of garlic. As the garlic is reproduced exclusively by vegetative means plant characters such as clove weight or size used for propagation also affect the bulb size, yield and quality of the produce significantly (Memane et al 2008). No doubt the use of the large sized cloves increases the yield significantly but it also enhances the cost of production by affecting the seed quantity whereas small sized bulbs result into lower yield with lesser cost of production. There is a great need to standardize the size of garlic cloves used for propagation in order to get cost effective results in garlic production (Castellanus et al 2004). Therefore the present investigations have been undertaken to study effect of clove weight and plant growth regulators on growth and yield of garlic (*Allium sativum* L).

MATERIAL and METHODS

The present investigations were carried out on Agrifound Parvati cultivar of garlic at Pandah experimental farm of Seed Technology and Production Centre, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP during Rabi 2009-10. The experiment was laid out on 10 October 2009 in randomized block design (factorial) with three replications of each treatment combination (clove weight x growth regulator). The 30 treatments comprised of six clove weights viz W_1 (1.0-1.5 g), W_2 (1.6-2.0 g), W_3 (2.1-2.5 g), W_4 (2.1-2.5 g), W_5 (3.1-3.5 g) and W_6 (3.6-4.0 g) and four growth regulators viz G_1 (Cycocel 500 ppm), G_2 (Cycocel 1000 ppm), G_3 (Paclobutrazol 500 ppm), G_4 (Paclobutrazol 500 ppm) and G_5 as a control (water). The cloves were sown at a spacing of 20 cm x 10 cm in a plot having size of 1.0 x 1.5 m^2 accommodating 75 plants per plot. The spray of growth regulators was done twice ie 1st week of March and one month later and water was applied as foliar spray in control plots. The standard cultural practices recommended

were followed to ensure a healthy crop stand (Anon 2009). The observations were recorded on plant height (cm), number of leaves per plant, bolters (%), biomass yield per plot (kg) and bulb yield per plot (kg) from twenty five randomly selected plants. The mean values of data were subjected to analysis of variance as described by Gomez and Gomez (1984) for factorial randomized block design.

RESULTS and DISCUSSION

The analysis of variance indicated highly significant differences for the effect of clove weight and plant growth regulators on growth and yield of garlic (Table 1).

Plant height (cm)

Although plant height is a genetically controlled character in garlic it can be altered by the use of different clove weights and various plant growth regulators (Govindkrishana and Sahota 1984, Arora et al 1998, Alam and Islam 1989, Madalgeri and Ganiger 1993, Gasti 1994). A perusal of data presented in the Table 2 reveal that minimum plant height (45.49 cm) was obtained with the clove weight W_1 (1.0-1.5 g) whereas maximum plant height (53.55 cm) was observed with the clove weight W_5 (3.1-3.5 g). Higher vegetative growth under large clove size might be due to more reserve food material present in the clove in the initial stage of the growth (Deka and Shadeque 1993). These results are in line with Kotagriwar et al (1997) who were also of the opinion that larger size cloves result in increased plant height due to more reserve food material present in the clove during initial stages of growth in garlic. The authors did not worked with extra-large sized cloves in garlic. However in the present studies the increase in plant height remained consistent up to W_5 and reduced afterwards in W_6 (3.6-4.0 g). It might be due to the fact that presence of extra food material over the saturation level does not affect the plant height significantly. Singh (2000) and Memon et al (2009) also reported that medium sized corms produce more plant height as compared to large sized corms in gladiolus. In case of the effect of plant growth regulators minimum plant height (49.01) resulted with the growth regulator G_2 (Cycocel 1000 ppm) and maximum plant height (53.06 cm) was obtained with the control G_5 (water). Reduction in plant height due to application of growth regulators appears to be due to slowing down of cell division and reduction in cell expansion. It has been reported that Cycocel is an anti-gibberellin dwarfing agent leading to deficiency of gibberellin in the plant and reduces the growth by blocking the conversion of geranyl pyrophosphate to copalyl pyrophosphate which is the first step of gibberellin synthesis (Moore 1980). Thus reduction in plant height is due to retardation of transverse cell division particularly in cambium which is the zone of meristamatic activity at the base of the internode (Grossman 1990). Deotale et al (1994) and Garai and Datta

(2003) reported that application of Cycocel decreased the plant height in green gram as compared to control. Mehetre and Lad (1995) also found decrease in plant height due to application of Cycocel. The interaction studies revealed that W_1 x G_2 (clove weight 1.0-1.5 g x cycocel 1000 ppm) gave the minimum plant height (41.57 cm) due to minimum availability of reserve food material and growth retarding effect of Cycocel. Maximum plant height (54.73 cm) was obtained with the interaction between W_5 x G_5 (clove weight 3.1-3.5g x control water) due to utmost availability of reserve food material to the plant in the initial stages of its growth and non-application of any growth retarding substance.

Number of leaves per plant

Leaf is considered as an important functional unit of plant which contributes to yield through its photosynthetic activity. The data in Table 2 show that among all the clove weights W_5 (3.1-3.5 g) resulted in maximum number of leaves per plant (14.63) and clove weight W_1 (1.0-1.5 g) gave the minimum number of leaves per plant (12.56). It might be due to comparatively more reserve food material present in the larger cloves than in smaller ones. Similar results have also been reported by Memane et al (2008) for the effect of clove weight on number of leaves in garlic. Lesser number of leaves in W_6 (3.6-4.0 g) as compared to W_5 may be due to the lower plant height obtained in garlic with extra large sized clove weight. In case of growth regulators maximum number of leaves per plant (13.72) was obtained with the growth regulator G_2 (Cycocel 1000 ppm) and minimum number of leaves per plant (12.72) was found in G_5 (control). This may be due to the ability of growth retardants to delay senescence of leaf by arresting the chlorophyll degradation and protease activity and promoting the synthesis of soluble protein and photosynthetic enzyme (Canor and Prado 1983, Srivastava and Goswami 1988). Identical results have also been reported by Memane et al (2008) for the effect of Cycocel (1000 ppm) on number of leaves in garlic. Saisankar (2001) also reported that application of Cycocel (500 ppm) increased number of leaves in green gram. Prakash et al (2003), Hanchinamath (2005), Castro et al (1990) and Lakshminarasimhan (2002) reported the increase in number of leaves by growth regulators in black gram, cluster bean and sun flower. In the present studies interaction between W_5 x G_2 (3.1-3.5 g x Cycocel 1000 ppm) resulted in maximum number of leaves per plant (15.61) as compared to the combination W_1 x G_5 (1.0-1.5 g x control) in which number of leaves per plant were found minimum (12.23). It might be due to availability of more stored food material to the plant in the early growth stages and ability of growth regulator to delay senescence of leaf resulting in the enhanced foliage growth due to increased photosynthetic activity.

Table 1. Analysis of variance for various growth and yield characters in garlic

Character/source	Mean Sum of Squares*				
	df	Plant height (cm)	# leaves/plant	Biomass/ plot (kg)	Bulb yield/ plot (kg)
Replications	2	4.59	0.36	0.21	0.0627
Weight (W)	5	161.17*	10.41*	31.28*	21.160*
Growth regulator (G)	4	41.38*	2.58*	2.27*	0.6288*
W x G	20	5.80*	0.38*	0.36*	0.1001*
Error	58	1.62	0.13	0.07	0.0208
Total	89	214.59	13.88	34.20	21.9730

*Significant at 5% level of significance

Bolters (%)

Premature bolting in the garlic reduces the total crop yields and can be controlled by management of photoperiod and temperature or by influencing other growth and development stages (Kamenetsky et al 2004). Moreover bolting is a genetically inherited character as hard neck cultivars are bolting type whereas soft neck are non-bolting in nature. Therefore in the present studies no incidence of bolters (%) was recorded in the experimental field due to the non-bolting nature of the Agrifound Parvati cultivar of garlic.

Biomass yield per plot (kg)

An increase in the vegetative as well as reproductive growth of plants will lead to a higher production of plant biomass. The various processes such as vegetative meristem activities, cell elongation, photosynthetic efficiency and secondary wall biosynthesis are crucial for plant biomass production. These processes are either genetically controlled or can be altered by the use of growth regulators. In the present study highest biomass yield per plot (5.21 kg) was obtained with the clove weight W_5 (3.1-3.5 g) as compared to largest size clove weight W_6 (3.6-4.0 g) while clove weight W_1 (1.0-1.5 g) gave the lowest biomass yield per plot (1.62 kg) as given in Table 2. This might have happened because of the highest plant height, maximum number of leaves and heavy weight of bulb in W_5 as compared to other clove weights. These results are in line with Ramnivas and Singh (1998), Brar and Gill (2000), Deka and Shadeque (1993) and Kotagirwar et al (1997) reported in garlic. The growth regulator G_2 (Cycocel 1000 ppm) resulted in highest biomass yield per plot (4.09 kg) and lowest biomass yield per plot (3.15 kg) was obtained with the G_5 (control). It might be due to modification

Table 2. Effect of clove weight and plant growth regulators on growth and yield in garlic

Character	Plant height (cm)	# leaves/plant	Biomass yield/ plot(kg)	Bulb yield/ plot
Effect of clove weight on growth and yield in garlic				
W_1	45.49	12.56	1.62	0.86
W_2	48.25	12.60	2.15	1.53
W_3	51.73	12.84	3.81	2.53
W_4	52.65	13.94	4.49	3.42
W_5	53.55	14.63	5.21	3.79
W_6	53.48	13.07	4.61	3.48
$CD_{0.05}$	0.91	0.26	0.19	0.10
Effect of plant growth regulators on growth and yield in garlic				
G_1	50.78	13.30	3.67	2.61
G_2	49.01	13.72	4.09	2.83
G_3	51.38	13.13	3.50	2.52
G_4	50.05	13.49	3.84	2.70
G_5	53.06	12.72	3.15	2.34
$CD_{0.05}$	0.83	0.24	0.17	0.09
Interaction effect of plant growth regulators and clove weight on growth and yield in garlic				
$W_1 \times G_1$	45.08	12.67	1.73	0.91
$W_1 \times G_2$	41.57	13.00	1.59	0.83
$W_1 \times G_3$	45.93	12.40	1.57	0.85
$W_1 \times G_4$	43.73	12.52	1.68	0.88
$W_1 \times G_5$	51.13	12.23	1.54	0.81
$W_2 \times G_1$	47.07	12.65	2.10	1.50
$W_2 \times G_2$	46.20	12.32	2.34	1.62
$W_2 \times G_3$	48.33	12.83	2.22	1.56
$W_2 \times G_4$	48.70	12.83	2.22	1.56
$W_2 \times G_5$	50.93	12.35	1.90	1.40
$W_3 \times G_1$	52.27	12.62	3.66	2.45
$W_3 \times G_2$	49.57	13.33	4.23	2.75
$W_3 \times G_3$	53.47	12.46	3.48	2.36
$W_3 \times G_4$	50.13	13.22	4.12	2.70
$W_3 \times G_5$	53.20	12.56	3.56	2.40
$W_4 \times G_1$	53.53	14.23	4.78	3.57
$W_4 \times G_2$	50.67	14.45	5.00	3.68
$W_4 \times G_3$	54.17	13.92	4.47	3.40
$W_4 \times G_4$	51.13	13.83	4.38	3.36
$W_4 \times G_5$	53.77	13.27	3.85	3.08
$W_5 \times G_1$	53.33	14.73	5.29	3.84
$W_5 \times G_2$	52.00	15.61	6.24	4.33
$W_5 \times G_3$	53.73	14.52	5.07	3.72
$W_5 \times G_4$	53.93	15.07	5.65	4.02
$W_5 \times G_5$	54.73	13.22	3.79	3.05
$W_6 \times G_1$	53.40	12.93	4.47	3.41
$W_6 \times G_2$	54.07	13.61	5.15	3.76
$W_6 \times G_3$	52.67	12.63	4.18	3.25
$W_6 \times G_4$	52.68	13.47	5.00	3.69
$W_6 \times G_5$	54.60	12.70	4.24	3.29
$CD_{0.05}$	2.04	2.58	0.43	0.23

of source sink relationship by the use of growth regulators. The superiority of Cycocel in respect of the weight of biomass has also been reported by Das et al (1996) which confirms the above findings. The interaction between W_5 x G_2 (clove weight 3.1-3.5 g x Cycocel 1000 ppm) recorded the highest biomass yield per plot (6.24 kg). This might have happened due to the mutual effect of highest plant height, maximum number of leaves and heavy weight of bulb in W_5 and catalytic activity of the Cycocel resulting into enhanced biomass yield in garlic.

Bulb yield per plot (kg)

Yield is an important character which is responsible for the commercial feasibility of a crop variety and is also one of the most essential traits attaining highest consideration in a research programme. The data presented in Table 2 show that highest bulb yield per plot (3.79 kg) was obtained with the clove weight W_5 (3.1-3.5 g) as compared to extra large clove weight W_6 and clove weight W_1 (1.0-1.5 g) gave the lowest bulb yield per plot (0.86 kg). This might be due to the reason that highest plant height and highest average weight of bulb resulted in increased total yield with the clove weight W_5 as compared to other clove weights under study. The present studies are in congruent with Memane et al (2008) who reported that increased vegetative and bulb growth observed in large sized clove due to more reserve food materials might had helped in increasing the overall yield of garlic. Moreover in support of above findings Castellanous et al (2004) reported that extra large sized seed cloves do not yield more than the large sized cloves due to less number of cloves in the former ie extra large clove weight. For the effect of plant growth regulators highest bulb yield per plot (2.83 kg) was resulted with the growth regulator G_2 (Cycocel 1000 ppm) and lowest bulb yield per plot (2.34 kg) was obtained with the G_5 (control). The production of large sized bulbs with the Cycocel (1000 ppm) may be attributed to fact that growth regulators remain physiologically more active to build up sufficient food reserves for developing bulbs which ultimately lead to increased total yields (Memane et al 2008). Similar findings regarding the yield accelerating property of Cycocel (1000 ppm) have also been reported by Rahim and Fordam (1994) in garlic. Studies regarding the interaction between clove weight and growth regulators showed that the combination W_5 x G_2 (clove weight 3.1-3.5 g x Cycocel 1000 ppm) resulted in highest bulb yield per plot (4.33 kg). The combination W_1 x G_5 (clove weight 1.0-1.5 g x control) gave the lowest bulb yield per plot (0.81 kg). In the present investigations the combination W_5 x G_2 overpowered all other treatment combinations in terms of all growth and yield parameters which resulted into increased total yield in garlic.

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