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Nidhish Gautam
Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

HS Kanwar
Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

DK Mehta
Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Sandeep Kansal
Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Sandeep Kumar
Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Correspondence
Nidhish Gautam
Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India

Effect of clove weight and plant growth regulators on shelf-life of garlic (*Allium sativum* L.)

Nidhish Gautam, HS Kanwar, DK Mehta, Sandeep Kansal and Sandeep Kumar

Abstract
The present investigations were carried out in '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, during Rabi 2009-10. The treatments comprised of six clove weight and four growth regulators. The observations were recorded on neck thickness, physiological loss of bulb weight, sprouting incidence and dry matter content. Analysis of variance showed significant difference among all the treatment combinations for all the characters under study. Clove weight 'W_1' (1.0-1.5g) along with the growth regulator 'G_2' (Cycocel; 1000 ppm) performed best for the majority of the storage characters. Therefore, clove weight 'W_1' (1.0-1.5g) in combination with growth regulator 'G_2' (Cycocel; 1000 ppm) can be recommended to enhance the shelf-life of garlic under ambient storage conditions after multilocation testing.

Keywords: garlic; clove weight; cycocel; paclobutrazol

Introduction
Garlic (*Allium sativum* L.) is the most widely used cultivated *Allium* species after onion belonging to the family Amaryllidaceae. It has been originated in central Asia (Brewster, 1994) [1]. 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) [2]. 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) [3], antifungal (Hughes and Lawson, 1991) [4], antiviral (Meng *et al.*, 1993) [5] and antiprotozol properties (Reuter *et al.*, 1996) [6]. It is beneficial to cardiovascular and immune system and has antioxidant and anticancer properties (Harris *et al.*, 2001) [7].

Garlic productivity in India is comparatively low as compared to world. So, in the recent years, due attention has been given to improve storage life of garlic with the application of plant growth regulators, as they modify plant characters like neck thickness, sprouting of bulb, fresh and dry weight of bulb etc. by influencing the physiological processes, cell elongation, cell multiplication within the plant, which ultimately affect the yield and quality of garlic. As the garlic is reproduced exclusively by vegetative means, so plant characters such as clove weight or size used for propagation also affect the quality of the produce, significantly (Memane *et al.*, 2008) [2]. So, 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) [8]. Besides this, during storage under ordinary conditions, losses due to rotting, sprouting and drying can occur. Hence, improvement of storage life of garlic is a great challenge before us, because during times of over-supply at harvesting in May-June, market price is reduced. Therefore, for regular supply and fair profit, it is necessary to increase the shelf-life of garlic without compromising quality deterioration. Plant Growth Regulators play an important role in increasing self-life of garlic under ambient temperature conditions. Therefore, it is imperative to study the effect of other growth retardants on storage-life of garlic (Sharma *et al.*, 2010). Therefore, the present investigations have been undertaken to study the effect of clove weight and plant growth regulators on storage-life of garlic (*Allium sativum* L.) cv. Agrifound Parvati.

Materials 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. The experiment was laid out on 10th

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 W1 (1.0- 1.5 g), W2 (1.6-2.0 g), W3 (2.1-2.5 g), W4 (2.1-2.5 g), W5 (3.1-3.5 g) and W6 (3.6-4.0 g) and four growth regulators viz G1 (Cycocel 500 ppm), G2 (Cycocel 1000 ppm), G3 (Paclobutrazol 500 ppm), G4 (Paclobutrazol 500 ppm) and G5 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 i.e. 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. The observations were recorded Neck thickness (cm)**,** Physiological loss of bulb weight (%)**,** Sprouting incidence (%)**,** Dry matter content (%) 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 shelf life of garlic (Table 1).

Neck thickness (cm)

Neck thickness is the measure of quality of bulbs produced in garlic, which affect the storage life of the garlic. Greater the neck lesser will be the storage life and vice versa. In the present findings, clove weight 'W_1' (1.0-1.5 g) gave the thinnest neck (0.58 cm), whereas, thickest neck (1.04 cm) was obtained with the clove weight 'W_5' (3.1-3.5 g). It appears that least neck thickness in the clove weight 'W_1' may be due to availability of less stored food material to the plant in the early growth stages, which lead to the lesser neck growth and development. The results of the present findings are in conformity with Singh and Singh (2003) [11], who also reported that large size of bulb used for planting in case of onion produces greater neck thickness in comparison to smaller sized bulbs. Among the growth regulators, thinnest neck (0.82 cm) was attained with the 'G_5' (control; water), whereas thickest neck (0.89 cm) was obtained with growth regulator 'G_2' (cycocel; 1000 ppm). Highest neck thickness in case of 'G_2' is due to the fact that growth regulators increased the number of leaves per plant with increased photosynthetic activity and ultimately leading to more plant growth in terms of neck thickness. The present findings are in line with (Memane *et al.*, 2008) [2], who also reported maximum neck thickness with cycocel (1000 ppm). Among the interaction studies, the combination W_1 x G_5 (Clove Weight; 1.0-1.5g x Control; Water) gave the thinnest neck (0.55 cm), while W_5 x G_2 (3.1-3.5g x Cycocel; 1000 ppm) resulted in thickest neck (1.10 cm). Lowest neck thickness in the former combination might be due to poor availability of food material as a result of interaction between them

Physiological loss of bulb weight (%)

The present investigations revealed that minimum physiological loss of bulb weight (9.76 %) after four months of storage was observed in the clove weight 'W_1' (1.0-1.5 g) and clove weight 'W_6' (3.6-4.0 g) gave the highest physiological loss of bulb weight (13.12 %). More physiological loss of bulb weight in large sized clove weight might be due to presence of more moisture content as compared to cloves of smaller weights. In case of growth regulators, minimum physiological loss of bulb weight (11.37 %) after four months storage was recorded with the growth regulator 'G_2' (Cycocel; 1000 ppm), whereas maximum physiological loss of bulb weight (12.07 %) was obtained with the 'G_5' (Control; water). Results are in opinion that cycocel and paclobutrazol have been reported to increase the peroxidase activity, which is helpful in removal of harmful radicals from chloroplast and cytosol that can help to enhance the storage life of bulb with minimizing the physiological loss of bulb weight during storage. The interaction studies showed that minimum physiological loss of bulb weight (9.23 %) after four months of storage was obtained with the combination W_1 x G_2 (Clove Weight; 1.0-1.5 g x Cycocel; 1000 ppm). While, the interaction between W_6 x G_5 (Clove Weight; 3.6-4.0 g x Control; water) gave the maximum physiological loss of bulb weight (13.57 %). Minimum physiological loss of bulb weight in W_1 x G_2 might be due to integrated effect of smallest clove size and ability of growth regulators to reduce the transpirational losses during the storage. These results are in line with Shafi (1978) [12], Randhawa *et al.* (1987) [13] and Singh *et al.* (1998) [14], who reported the minimum physiological loss of bulb weight in onion by the application of Maleic hydrazide stored in ambient storage conditions.

Sprouting incidence (%)

Sprouting incidence is an important parameter which determines the quality of the bulbs after storage. Six months after the storage, clove weight 'W_1' (1.0-1.5 g) gave the minimum sprouting incidence (50.65 %). While, clove weight 'W_6' (3.6-4.0 g) gave the maximum sprouting incidence (64.92 %) It might be due to the fact that lager sized clove weight have more moisture content in comparison to smaller one, which lead to higher sprouting incidence during the storage. In case of growth regulators; minimum sprouting incidence (57.89 %) was obtained with the growth regulator 'G_2' (Cycocel; 1000 ppm) This is due to the reason that, growth regulators have the property to reduce the moisture content of the cloves, which results in reduced cell activities and hence the minimum sprouting. The interaction between clove weights and growth regulators revealed that the combination W_1 x G_2 (Clove Weight; 1.0-1.5 g x Cycocel; 1000 ppm) gave the minimum sprouting incidence (49.04 %).Whereas, maximum sprouting incidence (65.39 %) was obtained with the interaction between W_6 x G_5 (Clove Weight; 3.0-3.5 g x Cycocel; 1000 ppm). The mutual effect of lowest clove weight and effect of growth regulator might be possible reason of minimum sprouting in W_1 x G_2. Similar findings have also been reported by Mahadevaswamy (1984) [15], Randhawa *et al.* (1987) [13], Shukla and Namedo (2000) [16] and Singh *et al.* (1998) [14] in case of onion by the application of Maleic hydrazide.

Dry matter content (%)

Dry matter production particularly in the reproductive organs of the plants is an important yield contributing character in garlic. The present studies revealed that maximum dry matter content (26.97 %) was observed with the clove weight 'W_1' (1.0-1.5g). Whereas, Minimum dry matter content (22.23 %) was obtained with the clove weight 'W_5' (3.1-3.5g). This might be due to the fact that larger sized cloves have more moisture content comparatively which results in higher physiological losses and ultimately lower percentage of dry matter content. Among the plant growth regulators, maximum dry matter content (26.07 %) was obtained with the growth

regulator 'G_2' (Cycocel; 1000 ppm). Minimum dry matter content (24.19 %) was resulted with the control G_5 (water). High dry matter content with the application of growth regulators might be due to reduction in moisture content of the bulbs by the activity of growth regulators. Studies on interaction between W_1 x G_2 (Clove Weight; 1.0-1.5 g x Cycocel; 1000 ppm) gave the highest dry matter content (27.36 %) and lowest dry matter content (21.39 %) was obtained with the combination W_6 x G_5 (Clove Weight; 3.6-4.0 g x Control; water). Higher dry matter content in W_1 x G_2 is probably due to combined effect of both the superior factors used in the treatment. These results are in line with Kumar *et al.* (2000) [17], who reported the highest dry matter recovery in onion with the application of Maleic hydrazide (3000 ppm) stored in ambient storage conditions.

Table 1: Analysis of variance for various storage characters in garlic

Characters Source	df	Mean Sum of Squares*			
		Neck thickness (cm)	Physiological loss of bulbweight (%) 05 September	Sprouting incidence (%) 31st October	Dry matter content (%)
Replications	2	0.0021	0.0011	3.1065	0.0122
Weight (W)	5	0.4416*	0.4904*	167.6387*	0.4458*
Growth regulator (G)	4	0.0132*	0.0287*	3.6710*	0.0960*
W x G	20	0.0014*	0.0184*	0.2840*	0.0139*
Error	58	0.0005	0.0003	0.3295	0.0040
Total	89	0.4590	0.5391	175.0312	0.5721

* Significant at 5% level of significance

Table 2: Effect of clove weight and plant growth regulators on Shelf life of garlic

Character	Neck thickness (cm)	Physiological loss of bulb weight (%)	Sprouting incidence (%)	Dry matter content (%) in garlic
Effect of clove weight on Shelf life of garlic				
W_1	0.58	9.76(3.12)	50.65(45.35)	26.97(5.19)
W_2	0.74	10.89(3.30)	54.26(47.43)	26.58(5.16)
W_3	0.87	11.43(3.38)	56.48(48.70)	25.80(5.08)
W_4	0.99	12.35(3.51)	61.59(51.68)	24.91(4.99)
W_5	1.04	12.42(3.32)	64.03(53.13)	24.74(4.97)
W_6	0.93	13.12(3.62)	64.03(53.13)	22.23(4.71)
CD $_{(0.05)}$	0.02	0.01	0.41	0.10
Effect of Growth regulators on Shelf life of garlic				
G_1	0.86	11.52 (3.39)	58.28(49.77)	25.17(5.03)
G_2	0.89	11.37 (3.37)	57.89(49.65)	26.07(5.11)
G_3	0.85	11.75 (3.42)	58.88(50.12)	24.87(4.99)
G_4	0.87	11.59 (3.40)	58.33(49.80)	25.62(5.06)
G_5	0.82	12.07 (3.47)	59.89(50.71)	24.19(4.91)
CD $_{(0.05)}$	0.02	0.01	0.38	0.04
Interaction effect of clove weight and Growth regulators on Shelf life of garlic				
$W_1 \times G_1$	0.60	9.54 (3.09)	50.62(45.34)	26.78(5.17)
$W_1 \times G_2$	0.58	9.23 (3.04)	49.04(44.43)	27.36(5.23)
$W_1 \times G_3$	0.58	9.69 (3.11)	50.88(45.48)	26.62(5.16)
$W_1 \times G_4$	0.60	9.60 (3.10)	50.02(45.00)	27.16(5.21)
$W_1 \times G_5$	0.55	10.76 (3.28)	52.70(46.53)	26.94(5.19)
$W_2 \times G_1$	0.73	10.55 (3.25)	53.68(47.09)	26.42(5.14)
$W_2 \times G_2$	0.75	10.49 (3.24)	53.36(46.91)	27.10(5.21)
$W_2 \times G_3$	0.74	10.92 (3.31)	55.03(47.87)	26.77(5.17)
$W_2 \times G_4$	0.74	10.72 (3.27)	53.63(47.06)	26.77(5.17)
$W_2 \times G_5$	0.71	11.74 (3.43)	55.60(48.20)	25.84(5.08)
$W_3 \times G_1$	0.86	11.06 (3.33)	55.71(48.26)	25.45(5.04)
$W_3 \times G_2$	0.90	11.12 (3.33)	56.00(48.43)	26.74(5.17)
$W_3 \times G_3$	0.84	11.28 (3.36)	56.31(48.61)	25.05(5.00)
$W_3 \times G_4$	0.89	11.37 (3.37)	56.37(48.64)	26.51(5.15)
$W_3 \times G_5$	0.85	12.32 (3.51)	58.00(49.59)	25.24(5.02)
$W_4 \times G_1$	1.01	12.17 (3.49)	12.92 (3.60)	25.48(5.05)
$W_4 \times G_2$	1.03	12.05 (3.47)	12.35 (3.51)	25.90(5.09)
$W_4 \times G_3$	0.99	12.34 (3.51)	13.17 (3.63)	24.87(4.99)
$W_4 \times G_4$	0.98	12.11 (3.48)	12.67 (3.56)	24.69(4.97)
$W_4 \times G_5$	0.95	13.09 (3.62)	10.97 (3.31)	23.61(4.86)
$W_5 \times G_1$	1.05	12.92 (3.60)	12.86 (3.59)	24.93(4.99)
$W_5 \times G_2$	1.10	12.35 (3.51)	13.00 (3.61)	26.63(5.16)
$W_5 \times G_3$	1.03	13.17 (3.63)	13.07 (3.62)	24.52(4.95)
$W_5 \times G_4$	1.07	12.67 (3.56)	13.09 (3.62)	25.59(5.06)
$W_5 \times G_5$	0.94	10.97 (3.31)	13.57 (3.68)	22.01(4.69)
$W_6 \times G_1$	0.92	12.86 (3.59)	64.69(53.53)	21.97(4.69)
$W_6 \times G_2$	0.97	13.00 (3.61)	64.27(53.27)	23.27(4.82)
$W_6 \times G_3$	0.90	13.07 (3.62)	65.28(53.88)	21.52(4.64)
$W_6 \times G_4$	0.96	13.09 (3.62)	64.95(53.68)	23.00(4.8)
W6×G5	0.91	13.57 (3.68)	65.39(53.94)	21.39 (4.62)
CD (0.05)	0..04	0.03	0.92	0.10

*Figures in the parenthesis are square root transformed

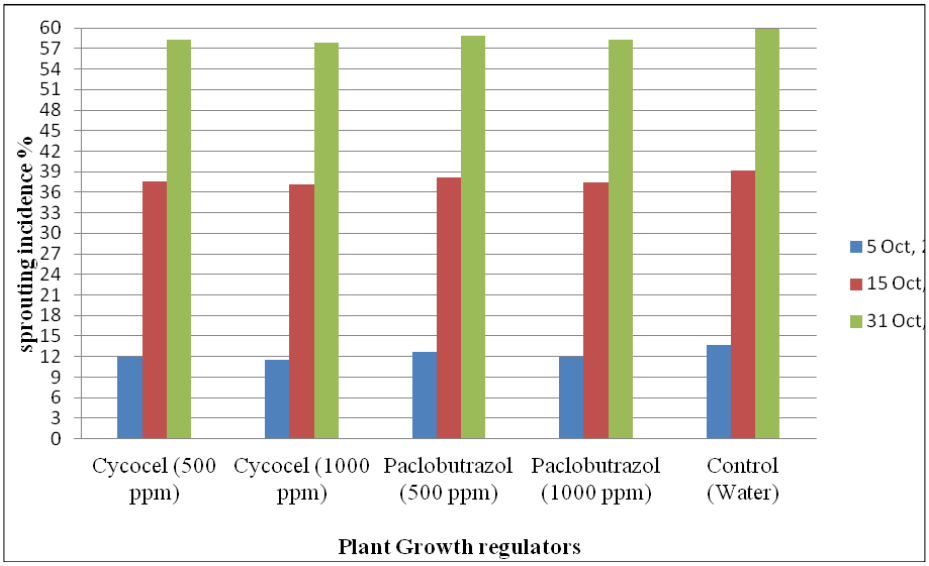

Fig 1: Comparison of effect of Plant Growth regulators on sprouting incidence at different storage intervals

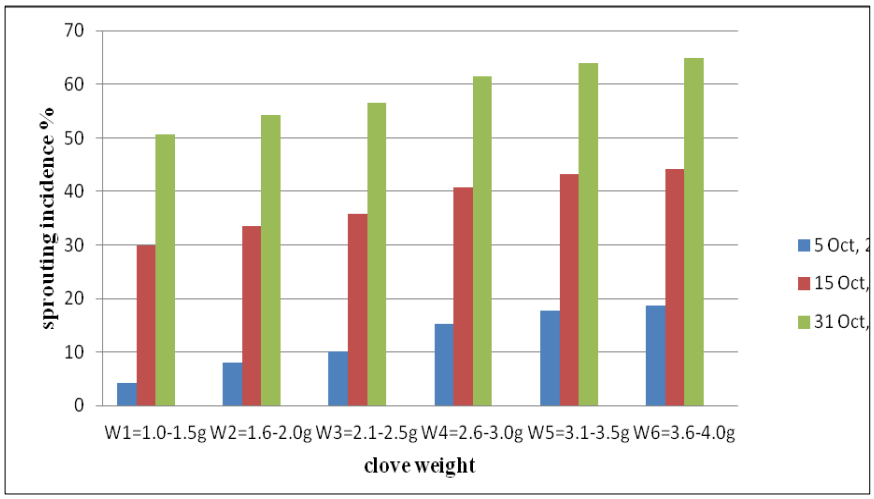

Fig 2: Comparison of effect of Clove Weight on sprouting incidence at different storage intervals

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