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Research Paper

Effect of sowing durations and planting geometries on growth, productivity and quality of garden cress (*Lepidium sativum*)

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2011–12 and 2012–13 on a clay loam soil at Udaipur, Rajasthan, to study the effect of sowing durations and planting geometries on growth, productivity and quality of garden cress or *chandrasur* (*Lepidium sativum* L.). The treatments comprising 4 sowing durations (41 standard meteorological week 8–14 October, 43th standard meteorological week 22–28 October, 45 standard meteorological week 05–11 November, 47th standard meteorological week 19–25 November) and 4 stand geometries (30 cm × 10 cm, 30 cm ×15 cm, 40 cm × 10 cm, 40 cm × 15 cm) were laid out in factorial randomized block design (RBD). Significantly the highest number of branches (18.8), dry-matter accumulation by plants, crop-growth rate (CGR) (31.2 g/m^2/day at 80–100 days after sowing), days to 50% flowering and days to 50% pod formation and seed yield (2.2 t/ha), straw yield (8.7 t/ha) and quality traits were recorded when crops was sown during 43 standard meteorological week. While sowing during 43 and 41 standard meteorological weeks being at par with each other. The highest net returns (₹75.1×10^3/ha) and benefit: cost ratio (4.4) were also recorded with 43 standard meteorological week. Planting geometries at 30 cm × 10 cm resulted in significantly highest crop-growth rate (CGR) (29.4 g/m^2/day at 80–100 DAS), seed yield (2.0 t/ha) straw yield (8.3 t/ha), net returns (₹68.0 × 10^3/ha) and benefit: cost ratio (4.0) over other planting geometries and remained at par with planting geometry at 40 cm × 10 cm. Therefore, crop sown with 43 standard meteorological week at 30 cm × 10 cm planting geometries for obtaining higher seed yield, quality traits and net returns.

Key words : *Chandrasur*, Net returns, Quality, Sowing durations, Standard meteorological week, Stand geometries, Yield

Garden cress or *chandrasur* a fast growing, edible winter season annual herb, which is botanically related to mustard sharing peppery, rangy flavour and aroma, has great medicinal values. The species is believed to originate in West Asia, from where, it spread to rest of the world including India (Joshi, 2008). The seeds are mainly used in preparation of medicines but roots and leaves also have therapeutic values. Mucilage present in the seed-coat is used to treat irritation of the mucous membrane of intestine in diarrhoea and dysentery (Maiti, 2008). Seeds contain volatile essential oils, which possesses anti-oxidantal properties and other medicinal values. Phenolic compounds exist widely in the plants. Similarly, it contains sinapic acid and its derivatives, most notable sinapic (Nayak *et al.,* 2009). Seeds are also fed to cattle to enhance the quality and quantity of milk. It is estimated that the total area under this crop in India is about 8,450 ha. The major *chandrasur*-growing states are Rajasthan, Madhya Pradesh, Gujarat, Uttar Pradesh and Maharashtra. The average productivity at present is very low (320 kg/ha), mainly due to lack of appropriate agro-techniques. Intensive efforts are required to remove constraints in achieving higher productivity and quality, particularly with respect to its sowing duration and stand geometry. Weather conditions to which the crop is exposed during its life-cycle is considered to be principal input parameters affecting its productivity, despite availability of other inputs and improved crop husbandry practices (Mavi, 1986). Thus, sowing duration is one important and decisive factor that has direct bearing on weather conditions. The different growth phases of the crop should synchronize with optimum environmental conditions for better expression of emergence, growth and yield. Harmonious balance of veg-

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etative and reproductive phases for successful crop production has been stressed upon by (Brown and Ware, 1958). Therefore, evolving appropriate sowing duration for this crop under prevailing conditions seems to be of paramount importance for achieving higher yield and quality. Optimum planting geometry provides conditions for efficient utilization of weather parameters. Maintenance of optimum plant population through appropriate geometry may govern the shape, size and area of leaf; thereby affect efficient interception of radiant energy incident to the crop surface and entire depth of canopy and growth of plant canopy on one hand, and it affects microclimate of the crop on the other hand. Thus, plant density per unit area maintained through specific geometry and the yield/plant are 2 interdependent factors responsible for crop yield (Singh and Dhillon, 1991). Keeping the above facts in view, an experiment was conducted to study the growth, productivity and quality of *chandrasur* as influenced by sowing durations and planting geometries.

MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*) seasons of 2011–12 and 2012–13 at Instructional Agronomy Farm, College of Agriculture, Udaipur, is situated in the lap of Aravalli hills at (24° 35' N and 74° 42' E with an altitude of 579.5 m above mean sea-level). The region falls under the agro-climatic zone IV-a (Sub-humid Southern plain and Aravalli hills of Rajasthan). Average annual rainfall of the region is around 600 mm. The soil was clay loam and alkaline (pH 8.1). The soil was medium in available nitrogen (272.3 and 281.4 kg/ha) and phosphorus (18.41 and 19.57 kg P_2O_5/ha and high in available potassium 361.82 and 369.25 kg K_2O/ha respectively). The experiment was laid out in factorial randomized block design (RBD) with 3 replications, having 16 treatment combinations of 4 sowing durations, [41 standard meteorological week (08–14 October), 43 standard meteorological week (22–28 October), 45 standard meteorological week (05–11 November) and 47 standard meteorological week (19–25 November)] and 4 planting geometries (30 cm × 10 cm, 30 cm × 15 cm, 40 cm × 10 cm and 40 cm × 15 cm). The gross and net plot size were 3.6 m × 4.2 m and 2.4 m × 3.3 m during both the years of experimentations. *Chandrasur* variety 'MC 1' was sown @ 8–10 kg/ha as per treatment during both the years. The seeds were covered with the thin layer of soil and irrigation was given immediately after sowing through a slow stream. Nitrogen (60 kg N/ha) and phosphorus (30 kg/ha P) were applied in the form of urea and single superphosphate (SSP), respectively. Half dose of nitrogen and full dose of phosphorus 30 kg P_2O_5/ha were applied basal by pora method. Remaining nitrogen was top-dressed at the second irrigation. To keep the crop free from weeds, 2 manual weeding and 1 hoeing were done, first at 30 days after sowing (DAS) and second at 60 DAS. Dry-matter accumulation was recorded at 100 DAS and at harvesting by collecting 5 random whole plant samples in each plot. Number of branches/plant at harvesting and seed yield/plant were recorded from 5 random plants from each plot at harvesting and mean values were computed. Crop-growth rate (CGR) between 80–100 DAS were recorded on the basis of dry-matter accumulation as per procedure given by Redford, (1967).

Days to 50% flowering and 50% pod formation were recorded from each plot. Seed and straw yield (t/ha) were calculated based on per plot yield. Harvest index (%) was also worked out. Total oil yield of seeds (kg/ha) was recorded (A.O.A.C. 1995). Volatile essential oil yield of seeds (kg/ha) was also recorded as per method given by Shaath *et al.,* (1992). Mucilage yield of seeds (kg/ha) was recorded as per Varsha *et al.,* (2010). Phenol yield of seeds (kg/ha) was calculated as per Malik and Singh (1980). Economic analysis was done on the basis of prevailing market prices of inputs and output obtained from each treatment. The statistical analysis of the data was done Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth attributes

Growth attributes, viz. number of branches/plant, crop-growth rate (CGR), dry-matter accumulation by plant, 50% flowering and 50% pod formation (Table 1) indicate that sowing during 41 and 43 standard meteorological weeks being at par with each other, was significantly superior to 45 and 47 standard meteorological weeks with respect to branches/plant during both the years and on pooled basis. Sowing during 43 standard meteorological week increased branches/plant by 16.0 and 33.3% over sowing during 45 and 47 standard meteorological weeks respectively. It was noticed that branches/plant were increased significantly with the increase in ground area available/plant, i.e. with reduction in plant population/ha. The widest planting geometry (40 cm × 15 cm) produced plants having significantly the highest number of branches, which was followed by 30 cm × 15 cm, 40 cm × 10 cm and 30 cm × 10 cm. Further, 30 cm × 15 cm was also found superior to 40 cm × 10 cm and 30 cm × 10 cm, but variation between later 2 was found statistically at par with each other. Increases in branches/plant with 40 cm × 15 cm planting geometry were 8.5, 22.4, and 26.4% compared to 30 cm × 15 cm, 40 cm × 10 cm and 30 cm × 10 cm, respectively, on pooled basis. It was observed that 43 meteorological week, sown crop achieved significantly the highest crop growth rate at 80–100 DAS. This might be attributed to availability of more favourable weather parameters at critical growth stages of crop under 43 standard meteorological week in comparison to other sowing durations. As a consequence of high crop growth rate the crop sown during 43 standard meteorological week accumulated significantly the highest dry-matter particularly at 100 days after sowing (DAS) and harvesting. Significantly the highest dry-matter accumulation/plant was recorded due to sowing during 43 standard meteorological week during both the years, which was followed by sowing during 41, 45 and 47 standard meteorological weeks. Thus, significantly higher dry-matter accumulation/plant during 43 standard meteorological week was linked with corresponding significantly higher crop growth rate (CGR). Planting geometry 30 cm × 10 cm recorded significantly higher CGR over all the other geometries. Among different planting geometries, 40 cm × 15 cm recorded the lowest CGR values at different growth stages. Since CGR relates to per day dry-matter accumulation in a unit area, therefore, variations in CGR among more spaced geometry 40 cm × 15 cm and the least spaced geometry 30 cm × 10 cm constituting the 2 extremes (the lowest and highest, respectively) of CGR needs to be analyzed in a rational manner. The lowest CGR under 40 cm × 15 cm reveal that though plants were the most healthy (maximum dry-matter/plant) in this treatment, but daily growth in plant dry matter in the unit area declined to minimum on account of exactly 50% plant population against plant population in 30 cm × 10 cm spacing. The statement vice-versa to previous statement stands true for 30 cm × 10 cm geometry. Dry-matter accumulation/plant was influenced significantly at 100 days and at harvest a definite change in the effect of sowing durations was noticed with the advancement of plant-growth stages with respect to dry-matter accumulation at 100 days and harvest. Significantly the highest dry-matter/plant was recorded due to sowing during 43 standard meteorological week during both the years, which was followed by sowing during 41, 45 and 47 standard meteorological week (Table 1). Also due to various planting geometries significantly the highest dry-matter was recorded under 40 cm × 15 cm at both these stages. Next to this treatment was 30 cm × 15 cm planting geometry, which was found at par with 40 cm × 10 cm but significantly superior to 30 cm × 10 cm in this respect. These finding corroborates the findings of Maiti, (2009).

In present study, 43 standard meteorological week sown crop took significantly the highest number of days to 50% flowering, days to 50% pods formation (Table 1), which shows that 43 standard meteorological week sown crop completed it's phasic development matched with the optimum requirement of temperature, which ultimately might have favoured the crop growth. The significant reduction in duration (growth period) under late-sown crop (45 and 47 standard meteorological weeks) and coinciding of reproductive phase with high temperature might have resulted in forced maturity of crop under delayed sowing. The significant reduction in dry-matter accumulation under 45 and 47 standard meteorological weeks sowing could be a scribed to significant reduction in days to 50% flowering, 50% pod formation therefore; shorter period was available for production of dry-matter. The fact that 43 standard meteorological week maintained higher

Table 1. Effect of sowing durations and planting geometries on growth attributes of garden cress (Pooled data of 2 years)

Treatment	Branches/plant at harvest	Dry matter accumulation (g/plant)		CGR ($g/m^2/day$)	Days to 50% flowering	Days to 50% pod formation
		100 DAS	At harvest	80–100 DAS		
Sowing durations						
41 SMW	18.3	92.9	99.4	20.8	56.0	82.2
43 SMW	18.8	98.6	107.2	31.2	60.3	84.7
45 SMW	16.2	82.0	87.1	17.7	53.8	74.9
47 SMW	14.1	73.4	75.6	15.7	44.1	70.2
SEm±	0.2	1.0	1.0	1.0	0.5	0.6
CD (P=0.05)	0.8	3.1	2.9	2.9	1.6	1.8
Stand geometries						
30 cm × 10 cm	15.1	83.2	88.8	29.4	53.9	78.5
30 cm × 15 cm	17.6	86.6	92.2	19.4	53.4	79.0
40 cm × 10 cm	15.6	85.7	91.3	21.9	53.6	76.5
40 cm × 15 cm	19.1	91.3	96.9	14.6	53.2	78.1
SEm±	0.2	1.0	1.0	1.0	0.5	0.6
CD (P=0.05)	0.8	3.1	2.9	2.9	NS	NS

NS, Non-significant; DAS, days after sowing; SMW, standard meterological week; CGR, crop-growth rate growth performance at different subsequent stages can be ascribed to significantly higher plant growth on account of more conversion of radiant energy into biomass due to a bigger size of photosynthetic apparatus and data on leaf length endorse this statement. Mahmud *et al.,* (2008) and Bala *et al.,* (2011) reported profound effect of sowing time and resulting influence of temperature, humidity and sunshine hours on growth of *Brassica* crops. Results of present investigation further show that 50% flowering and 50% pod formation were not influenced significantly due to various planting geometries (Table 1). In fact, during germination and emergence, there was no underground or above ground competition for available resources, therefore, effect of various planting geometries was non significant. Moreover, these characters are governed mainly by weather parameters and genetic make-up rather than planting geometry or arrangement of plants. Therefore planting geometries not likely to change these traits. These findings support reports of Charak, (2005).

Yield attributes and yield

The seed yield/plant (g), 1000-seed weight (g), seed and straw yields (t/ha) were significantly influenced by sowing durations (Table 2). The 43 standard meteorological week sown crop resulted seed yield/plant significantly highest compared to all the other sowing durations during both the years, which was followed both by 41 and 45 standard meteorological week sowings. Sowing during 47 standard meteorological week yielded seeds/plant significantly lowest during both the years. The 43 standard meteorological week resulted in 24.0% higher seed yield/plant compared to 41 standard meteorological week. Seed yield/plant was not influenced significantly due to various planting geometries. Sowing of *chandrasur* during 43 standard meteorological week being at par with 41 standard meteorological week, found significantly superior to 45 and 47 standard meteorological week with respect to 1,000-seed weight. Sowing during 41 standard meteorological week was found at par with 45 standard meteorological week, but both these were superior to 47 standard meteorological week in this regard. Sowing during 43 standard meteorological week increased the 1,000-seed weight by 5.2 and 25.0% over sowing during 45 and 47 standard meteorological week, respectively. 1,000-seed weight was maximum under 30 cm × 10 cm, 30 cm × 15 and 40 cm × 10 cm as compared to 40 cm × 15 cm planting geometry. It seems that sowing of crop during 43 standard meteorological week might have resulted in coinciding the favourable environmental factors, particularly temperature at various critical growth stages, viz. grand growth, active branching, flowering, seed development, which ultimately might have synthesized and diverted the photosynthates for development of appropriate vegetative structure, which ultimately influenced yield attributes and yield favorably. Thus, as a consequence of favourable weather conditions, improvement in growth and yield components under 43 standard meteorological week sown crop might have resulted in realization of higher seed yield compared to the other sowing durations. The significant increase in straw yield under 43 standard meteorological week sowing seems to be on account of improvement in growth of crop in terms of dry-matter accumulation along with the various morphological structures as evident by significant increase in dry-matter accumulation, branches/

Table 2. Yield attributes of garden cress as influenced by sowing durations and planting geometries (pooled data of 2 years)

Treatment	Seed yield/ plant(g)	1,000-seed weight (g)	Seed yield (t/ha)	Straw yield (t/ha)	Harvest index (%)	Net returns ($\times 10^3$/ha)	Benefit: cost ratio
Sowing durations							
41 SMW	10.4	2.0	1.7	7.5	19.0	56.0	3.3
43 SMW	12.9	2.0	2.2	8.7	20.4	75.1	4.4
45 SMW	11.4	1.9	1.9	7.6	20.1	61.5	3.6
47 SMW	9.9	1.6	1.6	6.4	19.9	48.9	2.9
SEm±	0.2	0.0	0.02	0.1	0.3	1.0	0.0
CD (P=0.05)	0.7	0.0	0.07	0.3	NS	2.9	0.1
Stand geometries							
30 cm × 10 cm	11.4	1.9	2.0	8.3	19.9	68.0	4.0
30 cm × 15 cm	11.7	1.9	1.8	7.38	19.9	58.0	3.4
40 cm × 10 cm	10.8	1.9	1.9	7.8	19.9	62.3	3.7
40 cm × 15 cm	10.8	1.8	1.7	6.9	19.8	53.2	3.1
SEm±	0.2	0.0	0.02	0.1	0.3	1.0	0.0
CD (P=0.05)	NS	0.0	0.07	0.3	NS	2.9	0.1

NS, Non-significant; SMW, standard meteorological week

*Based on prices of seed = 40,000/t and straw = 500/t plant due to 43 standard meteorological week sowing.

Significant reduction in seed and straw yields due to delayed sowing might be due to adverse effect of weather parameters, particularly temperature and humidity on growth and development of crop as discussed earlier. It seems that insufficient time was available for vegetative growth as the plant entered in the reproductive phase at a faster rate. The shorter growth period at early stage in late-sown crop might have been resulted in poor plant canopy development as evident of less plant height, branches, shorter leaf and less dry-matter accumulation. Generally, environmental variables may override genetic influences and as such, variations in weather parameters at different sowings exert their influence on the plant growth and ultimately yield. Mavi and Tupper, (2005) also stated that plant can realize its genetic potential or complete its genetically programmed phasic development under certain range of environmental factors. The results corroborate with the findings of Chundawat, (2008) and Choudhary *et al.,* (2010). There exist no significant variation in harvest index due to various sowing durations and planting geometries in either year of experimentation. These results are in close conformity with those obtained by Maiti and Jat, (2013) and Yadav *et al.,* (2013).

Significantly highest seed and straw yield (t/ha) was achieved under narrowest planting geometry of 30 cm × 10 cm and with each increase in available ground space/ plant (i.e. decrease in plant population/hectare), there was significant reduction in seed and straw yield. As explained earlier, narrow spacing accommodated 333.0×10^3 plants/ ha, which successively decreased under wider planting geometries i.e. 250×10^3 in 40 cm × 10 cm, 222×10^3 in 30 cm × 15 cm and 166×10^3 in 40 cm × 15 cm. Thus, it is clear that under narrowest planting geometry there were more number of main shoots and with each increase in spacing the reduction in main shoots took place, though these were substituted by emergence of more number of secondary and tertiary branches. It is well known fact that yield potential of main shoots generally remain higher than branches. Moreover, 1,000-seed weight of the seeds produced by main shoots also remain higher than the seeds produced by branches. Thus, increased number of plants/ main shoots/unit area under narrower planting geometries may be attributed to increase in seed and straw yield (t/ha) ha.

Significantly highest interaction effect of seed yield t/ ha was achieved due to interactive effect of sowing during 43 standard meteorological week at 30 cm × 10 cm planting geometry. (Table 3) The interaction effect of sowing durations and planting geometries was found statistically significant with respect to seed yield (t/ha). Sowing at planting geometries 30 cm × 10 cm and 40 cm × 10 cm, being at par produced significantly higher seed compared to 30 cm × 15 cm and 40 cm × 15 cm, when sowing was done during 41 and 45 standard meteorological week. However, sowing during 43 standard meteorological week at 30 cm × 10 cm stand geometry out yielded all other combinations. Significantly highest seed yield was achieved owing to sowing during 43 standard meteorological week at 30 cm × 10 cm planting geometry, while the least was under 47 standard meteorological week sown crop at 40 cm × 15 cm spacing. It is an establishment fact that a crop when sown at optimum time is able to exploit all the environmental factors efficiently in the process of dry-matter accumulation through various physiological and biochemical processes. Thus, accumulated dry matter eventually increases yield of crops. In this crop, it is not only sowing duration but planting geometry also plays vital role in deciding productivity and quality. *Chandrasur* plants require very specific environmental factors at various critical physiological growth stages with appropriate plant population arranged in efficient planting geometry. It seems that sowing of *chandrasur* during 43 standard meteorological week at 30 cm × 10 cm planting geometry during present study might have resulted in availability and exploitation of favourable environmental factors at various critical physiological growth stages. This might have increased accumulation of dry matter in plants result-

Table 3. Interaction effect of sowing durations and planting geometries on seed yield (t/ha) of garden cress crop (pooled data of 2 years)

Sowing durations	Planting geometries			
	30 cm × 10 cm	30 cm × 15cm	40 cm × 10 cm	40 cm × 15 cm
41 SMW	1.9	1.7	1.9	1.4
43 SMW	2.5	2.1	2.1	2.1
45 SMW	2.0	1.8	1.9	1.8
47 SMW	1.8	1.5	1.6	1.4
SEm±		0.05		
CD (P=0.05)		0.1		

SMW, standard meteorological week

Table 4. Effect of sowing durations and planting geometries on quality traits of garden cress (pooled data of 2 years)

Treatment	Total oil yield of seeds (kg/ha)	Volatile essential oil yield of seeds (kg/ha)	Mucilage yield of seeds (kg/ha)	Phenol yield of seeds (kg/ha)
Sowing durations				
41 SMW	378.1	1.8	257.0	17.8
43 SMW	498.4	2.2	333.1	23.6
45 SMW	361.4	1.9	277.1	19.1
47 SMW	300.3	1.6	227.7	15.6
SEm±	6.7	0.0	3.9	0.3
CD (P=0.05)	18.9	0.0	11.2	0.9
Stand geometries				
30 cm × 10 cm	441.3	2.0	302.1	20.8
30 cm × 15 cm	362.8	1.8	264.5	18.4
40 cm × 10 cm	404.5	2.0	281.0	19.9
40 cm × 15 cm	329.7	1.7	247.2	16.9
SEm±	6.7	0.0	3.9	0.3
CD (P=0.05)	18.9	0.0	11.2	0.9

ing in increase in various growth and yield attributes; and ultimately the yield of seeds and straw. The results of present investigation corroborates the findings of (Chouhan and Padiwal, 2014) and (Maiti and Jat 2013).

Economics

Net returns and benefit: cost ratio of the crop sown during 43 standard meteorological week were significantly highest compared to all other sowing durations (Table 2). It might be due to direct influence of higher seed and straw yields obtained under this sowing duration. Thus, there was a greater increase in the monetary value of seeds and straw obtained under 43 standard meteorological week sowing, without any additional cost. The results are in agreement to those obtained by Choudhary *et al.,* (2010), Maiti and Jat, (2013) and Yadav *et al.,* (2013). Among the planting geometries, net returns of ₹68,008/ha and benefit: cost ratio achieved due to narrowest planting geometry (30 cm × 10 cm), were significantly highest compared to wider planting geometries. This may be due to more seed and straw yield under this planting geometry compared to wider planting geometries with almost similar cost of cultivation for all stand geometries. The results are in close conformity to those reported by Maiti and Jat (2013) and Chouhan and Padiwal, (2014).

Quality traits

Further, yields of total oil, volatile essential oil, mucilage and phenol in terms of kg/ha were significantly highest under 43 standard meteorological week sowing (Table 4). Yield of these quality traits is a function of their content and seed yield. Thus, significant increase in yield of these parameters under 43 standard meteorological week sowing may be attributed mainly to increase in seed yield and secondarily to increase in their content in seed. Yield of various quality traits, viz. total oil, volatile essential oil, mucilage and phenol in terms of kg/ha, were also improved significantly owing to narrowest planting geometry (30 cm × 10 cm), and by adoption of wider planting geometries, there was successive reduction in these quality parameters yield, in fact is a product of content of that particular quality parameter in seed and seed yield. It is therefore logical to assume that increase in content of total oil and volatile essential oil of seeds coupled with increase in seed yield due to narrow stand geometries, ultimately resulted in significant increase in yield of these quality traits. Similarly, higher seed yield with non-significant difference in mucilage and phenol content of seeds resulted in significant increase in mucilage and phenol yield of seeds due to narrow planting geometries. These results are in close conformity to those obtained by Chouhan and Padiwal, (2014).

Thus, on the basis of results it is concluded that 43 standard meteorological week (22–28 October) at 30 cm × 10 cm planting geometry (333 × 10^3 plants/ha) is most suitable to increased productivity, profitability and quality of chandrasur crop under Udaipur conditions.

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