Performance of consecutive sowing of Amaranthus (*Amaranthus* spp.) types in different planting systems under shade net condition

Abstract

This study was conducted at the College of Horticulture,Dr.Balasaheb Sawant Konkan Krishi Vidyapeeth Dapoli, Ratnagiri,Dapoli, Maharashtra, during the rabi season of 2023-2024. A Factorial Randomized Block Design with eight treatments and four replications was used to evaluate the effects of four amaranthus types (V1: Konkan Durangi, V2: DPL-AS-6, V3: DPL-AS-4, V4: Nigadi Local) and two planting systems (B1: Flat bed, B2: Raised bed). The analysis of variance revealed significant differences in growth and yield parameters. Among the amaranthus types, Konkan Durangi (V1) exhibited the highest plant height (27.20 cm), stem diameter (5.10 mm), number of leaves per plant (9.17), and yield (15.59 t/ha). Raised bed planting (B2) resulted in superior plant growth, with higher plant height (26.35 cm), leaf size, and yield (14.42 t/ha). These findings suggest that both amaranthus type and planting system significantly influence growth and yield characteristics.

Keywords: Amaranthus types, planting systems, shade net

Introduction: Amaranthus is one of the oldest food crops in the world, with evidence of its use dating back to around 6700 BC. The genus Amaranthus includes over 60 species, including leafy vegetables, grain vegetables, ornamental plants, and weeds. The word amaranth is derived from the Greek word*amarantos*, which means *unwithering* and the people who used it symbolize immortality. Amaranth belongs to the genus *Amaranthus* within the family *Amaranthaceae*, which includes around 65 genera and 850 species. The genus *Amaranthus* itself comprises 50-60 species, many of which have edible leaves. Amaranthus is one of the tropical leafy vegetable crops, acquiring increasing importance as a potential subsidiary food crop for its excellent quality of protein and micronutrients (Devdas and Saroja, 2001). The leaves of Amaranthus are good sources of essential nutrients such as proteins (66.26 g/kg-11.38 g/kg), dietary fibers (91.94 µg/g-59.96 µg/g), fat (4.35 g/kg-1.42 g/kg), carbohydrates (98.54 g/kg-15.48 g/kg), minerals such as iron (1089.19 µg/g), calcium (10.13 mg/g), magnesium (30.01 mg/g), potassium (24.96 mg/g), and zinc (986.61 µg/g). Other nutrients like vitamins C (955.19 µg/g) and beta carotene (1043.18 µg/g) (Sarker and Oba, 2019. It hasahigh amount of essential amino acids as whole egg protein (Drzewiecki *et al.*, 2003). Many compounds and extracts from amaranth possessantidiabetic, antioxidant and antimicrobial activity (Anon., 2010). The leaf of Amaranthus has also been used asatea for relieving pulmonary conditions (Anon., 1992). Amaranth is highly nutritious, being rich in calcium and beta-carotene, which help strengthen bones and reduce the risk of osteoporosis. However, the absorption of these nutrients, including beta-carotene, calcium, and iron, by the human body is relatively low. This absorption largely depends on the quality of the fresh produce, the method of preparation, and the individual physical conditions of the consumers. Calcium in amaranth aids in muscle regeneration and helps stabilize blood pressure. Consuming 50-100 grams of amaranth leaves daily can significantly reduce the incidence of blindness in malnourished children, highlighting its potential in combating undernutrition and malnutrition. In the hills of Tamil Nadu, tribals use the juice from the leaves and stems of

Amaranthus spinosus to treat kidney stones. Studying amaranth cultivation under shade netting in the Konkan region during the Rabi season is crucial for maximizing production on limited land, mitigating the effects of fluctuating weather conditions, and enhancing the crop's growth, yield, and nutritional composition. Shade nets create a controlled environment that protects the plants from cold spells, unseasonal rains, and pests, leading to healthier growth and potentially higher yields. Additionally, this approach promotes sustainable farming by reducing the need for chemical inputs and contributes to food security by ensuring a consistent supply of nutrient-rich amaranth throughout the season.

Materials and Methods

The experiment trial was laid out at theCollege of Horticulture, Dapoli, Ratnagiri, Maharashtra during *rabi* seasonof year 2023-24 under shade net conditions. The experiment was carried out in a factorial randomized block design with two factors, eight treatments and four replications. Factor A: iscomposed of four Amaranthus types V_1: Konkan durangi, V_2: DPL-AS-6, V_3: DPL-AS-4, V_4: Nigadi Local and Factor: B iscomposed of two planting systems B_1: Flat bed, B_2: Raised bed. Data was recorded for different growth parameters like days required for germination, plant height (cm), number of leaves per plant, leaf length (cm), leaf breadth (cm), stem diameter (mm), days required forthe first harvest, number of harvestings, mean yield per square meter (kg) and mean yield (t/ha). To record the periodical observations at every harvest, ten plants were randomly selected and tagged in each treatment of all four replications.

Result and Discussion

Days required for germination

The data presented in (Table 1) revealed that in amaranthus types minimum days required for germination were recorded in V_1 (2.95) while, maximum days to germination were recorded in V_3 (4.69). Inthe case of planting systems, the minimum days to germination were recorded in system B_2, with an average of (3.32) days, while the maximum days were recorded in system B_1 (3.74). While in interaction, the minimum days to germination were recorded in interaction V_1B_2 (2.75), while the maximum days were observed in the V_3B_1 (5.18). Germination times in Amaranthus vary significantly due to genetic differences in the seeds. Raised beds can markedly accelerate germination by rapidly warming up, maintaining consistent temperatures, and enhancing drainage and aeration. These results are compared with the Dabhi *et al*. (2015) in spinach beet, Pawar (2019) Vasava *et al*. (2016) in Amaranthus.

Plant height (cm)

The data from (Table 1) observed that, in Amaranthus types, variety V_1 achieved the highest average plant height (27.20 cm), whereas V_3 had the shortest (24.59 cm). In the case of planting systems, B_2 showed the greatest average plant height (26.35 cm), whereas B_1 had the shortest average height (24.90 cm). While in interaction the highest average plant height was noted in the V_1B_2 interaction (28.28 cm), whereas the lowest was recorded in V_3B_1 (23.88 cm). Genetic diversity plays a crucial role in determining plant height in Amaranthus, even when different planting methods are used. Raised beds can improve growth conditions by enhancing soil warmth, drainage, and aeration, which may encourage taller plants. However, the ultimate height is predominantly influenced by the plant's genetic makeup.The results coincide with those of, Solangi *et al.* (2017) in spinach Deogirikar and Patil (2005), Jandge*et al.* (2018), Pawar (2019) and Dabholkar (2022) in amaranthus.

Number of leaves per plant

The data in (Table 2) indicates that in Amaranthus types, V_1 exhibited the highest leaf count with an average of 9.17, while V_3 showed the lowest leaf count (8.01). while in planting systems the B_2 planting system yielded the highest number of leaves, averaging (8.62), compared to the B_1 system, which produced fewer leaves (8.41). In interaction at harvest, the average number of leaves was highest in the V_1B_2 (9.39), whereas the lowest average was found in the V3B1 (7.95) leaves per plant. The number of leaves in Amaranthus is largely determined by genetic factors, even across various planting systems. While raised beds can enhance soil warmth, drainage, and aeration, potentially boosting leaf development, the final leaf count is primarily governed by the plant's genetic traits. Similar outcomes were given by Pawar (2019), Dabholkar (2022) in Amaranthus, andModupeola*et al.* (2018) in spinach.

Leaf length (cm)

The data presented in (Table 2) showed that V_4 had the longest leaf length with an average of 7.72 cm, while V_2 had the shortest (6.02 cm). While in planting systems B_2 observed thelongest leaf length (7.11 cm), while B_1 had the shortest (6.74 cm). Whereas in interaction, V_4B_2 had the longest average leaf length of 7.91 cm, while the V_2B_1 had the shortest (5.76 cm).The results are similartothose of Pharle (2016), Pawar (2019), Dabholkar (2022) in Amaranthus,andSolangi*et al.* (2017) in spinach.

Leaf breadth (cm)

Table 3 indicates that the type of Amaranthus, V_4 exhibited the largest leaf breadth, averaging 4.71 cm, whereas V_2 had the smallest breadth (3.18 cm). Inthe case of planting systems, the B_2 planting system achievedthe widest leaves with an average breadth of 4.05 cm, while B_1 had the smallest (3.71 cm). While interaction, V_4B_2 showed the greatest average leaf breadthof5.00 cm, whileV_2B_1 had the smallest (3.09 cm). The outcomes were similarly comparable to thoseofPharle (2016), Jandge*et al.* (2018), Pawar (2019), and Dabholkar (2022) in Amaranthus, Chauhan (2016) in spinach.

Stem diameter (cm)

Table 3 shows that inAmaranthus types, V_1 recorded maximum stem diameter, averaging 5.10 mm, whereas V_2 had the minimum average (3.54 mm). On theother hand in theplanting system B_2 showed the largest average stem diameter (4.26 mm), whereas B_1 had the smallest (4.01 mm) stem diameter. While interaction, the V_1B_2 achieved the highest average stem diameter of5.30 mm, whereas the V_2B_1 recorded the smallest average diameter of 3.50 mm. Stem diameter in Amaranthus varieties is predominantly influenced by genetic factors, even when grown in different planting systems. Raised beds can enhance growing conditions by improving soil warmth, drainage, and aeration, which may support better stem development. Outcomes were similar tothose of Mandal e*t al*. (2012),Pharle (2016), Pawar (2019), and Dabholkar (2022) in Amaranth,Modupeola*et al*. (2018) in spinach.

Days to first harvest

The data presented in (Table 4) on days to first harvestin thecase of Amaranthus types, the average number of days to first harvest wasminimum for V_1 (23.95), which was at par withV_2 (24.12). While V_3 took the maximum average time (26.25) to first harvest. While in planting, the minimum average days to harvest were recorded for B_2 (24.75), while B_1 had the maximum (25.06) to first harvest. Whereas in interaction, V_1B_2 had the minimum days (23.83) and V_2B_1 had the maximum days (26.42) for the first harvest. The number of days to harvest Amaranthus can be affected by the interaction between plant types and raised beds. Raised beds enhance conditions such as drainage, warmth, and aeration, potentially accelerating growth. However, the impact on harvest time also depends on the genetic characteristics of each Amaranthus variety.Similar results were reported by Pharle (2016), Vasava *et al*. (2016), Dabholkar (2022) in amaranthus, andSolangi*et al.* (2017) in spinach.

Number of harvestings

Table 4 shows that Amaranthustype V_1 recorded the maximum number of harvests with an average of 3.38, while V_3 had the lowest average (2.53). In thecase of planting systems, B_2 had the highest average number of harvestings (3.08), while B_1 had the lowest (2.88). While in interaction, V_1B_2 had the maximum average number of harvestings at (3.53), whereas V_2B_1 had the minimum, averaging (2.51). The interaction between Amaranthus types and raised beds can influence the number of harvests. Raised beds improve factors such as drainage, soil temperature, and aeration, which can lead to more vigorous growth and potentially increase harvest frequency. However, the genetic traits of each Amaranthus type also play a crucial role in determining the total number of harvests. These findings are consistent with those of Pharle (2016),andDabholkar (2022) in amaranth.

Mean yield per square meter(kg)

The data from (Table 5) observed that, in Amaranthus types, the V_1 variety achieved the highest mean yield of (1.56 kg) per square meter, demonstrating superior productivity. Conversely, the V_3 variety yielded the least, with a mean of 1.20 kg per square meter. While in planting systems, the highest mean yield was observed in planting system B_2, which produced (1.44 kg) per square meter. Conversely, planting system B_1 yielded the least, with a mean of 1.28 kg per square meter. In thecase of interaction the highest average yield was observed with the V_1B_2, producing (1.72 kg) per square meter, in contrast, the V_3B_1 recorded the lowest average yield at (1.13 kg) per square meter. Extreme weather conditions in open fields can severely restrict vegetable yield and quality. In these situations, protected cultivation, such as using raised beds, is ideal as it improves drainage, warms the soil, and enhances aeration, which can promote stronger plant growth and potentially increase yields. The outcomes were similarly comparable to thoseofPharle (2016), Vasava *et al*. (2016), Pawar (2019), Dabholkar (2022) in amaranth, Solangi *et al.* (2017) in spinach,Modupeola *et al*. (2018) in Lagos spinach.

Mean yield (t ha^{-1})

The data presented in (Table 5) revealed that Amaranthus types, the V_1 variety achieved the highest mean yield of 15.59 t/ha, demonstrating superior productivity. Conversely, the V_3 variety yielded the least, with a mean of 11.96 t/ha. While in planting systems, B_2 recorded the highest mean yield (14.42 t/ha), while B_1 produced a lower mean yield of 12.81 t/ha. On theother hand, interaction showed, the V_1B_2 achieved the highest mean yield of 17.18 t/ha, while V_3B_1 recorded the minimum mean yield of 11.31 t/ha. The interaction between Amaranthus types and raised beds can impact yields measured in tons per hectare. Raised beds generally improve conditions by enhancing drainage, increasing soil temperature, and boosting aeration, which can result in higher plant growth and potentially greater yields. The similar outcomes were given by Kotadia *et al*. (2012), Pharle (2016), Vasava *et al.*(2016), Mahajan *et al.* (2017), Pawar (2019), Dabholkar (2022) in Amaranthus, Solangi *et al*. (2017) in spinach, Modupeola *et al*. (2018) in Lagos spinach.

Table 1.Response of different Amaranthus types and planting systems on days required for germination and plant height under shade net conditions during *rabi* season.

	Days required for germination					**Plant height** (cm)				
	V_1	**V_2**	**V_3**	**V_4**	**MEAN**	**V_1**	**V_2**	**V_3**	**V_4**	**MEAN**
B_1	3.15	3.18	5.18	3.45	3.74	26.11	25.05	23.88	25.70	24.90
B_2	2.75	3.00	4.20	3.25	3.32	28.28	25.34	25.30	26.47	26.35
MEAN	2.95	3.09	4.69	3.35	3.52	27.20	25.20	24.59	26.08	25.62
	F-test	**S. Em (±)**		**CD @ 5%**		**F-test**	**S. Em (±)**		**CD @ 5%**	
V	**SIG**	0.03		0.09		**SIG**	0.15		0.45	
B	**SIG**	0.02		0.06		**SIG**	0.11		0.33	
V X B	**SIG**	0.04		0.12		**SIG**	0.21		0.64	

Table 2.Response of different Amaranthus types and planting systems on thenumber of leaves per plant and leaf lengthunder shade net conditions during *rabi* season.

	Number of leaves per plant					**Leaf length** (cm)				
	V_1	**V_2**	**V_3**	**V_4**	**MEAN**	**V_1**	**V_2**	**V_3**	**V_4**	**MEAN**
B_1	8.96	8.30	7.95	8.45	8.41	7.35	5.76	6.33	7.54	6.74
B_2	9.39	8.28	8.08	8.74	8.62	7.46	6.29	6.78	7.91	7.11
MEAN	9.17	8.29	8.01	8.60	8.52	7.41	6.02	6.55	7.72	6.93
	F-test	**S. Em (±)**		**CD @ 5%**		**F-test**	**S. Em (±)**		**CD @ 5%**	
V	**SIG**	0.05		0.15		**SIG**	0.07		0.21	
B	**SIG**	0.04		0.12		**SIG**	0.05		0.15	
V X B	**SIG**	0.07		0.21		**NS**	0.10		-	

Table 3.Response of different Amaranthus types and planting systems on leaf breadth and stem diameter under shade net conditions during *rabi* season.

	Leaf breadth (cm)					**Stem diameter** (mm)				
	V_1	**V_2**	**V_3**	**V_4**	**MEAN**	**V_1**	**V_2**	**V_3**	**V_4**	**MEAN**
B_1	4.07	3.09	3.29	4.41	3.71	4.90	3.50	3.57	4.09	4.01
B_2	4.34	3.28	3.60	5.00	4.05	5.30	3.59	3.91	4.26	4.26
MEAN	4.20	3.18	3.45	4.71	3.88	5.10	3.54	3.74	4.17	4.14
	F-test	**S. Em (±)**		**CD @ 5%**		**F-test**	**S. Em (±)**		**CD @ 5%**	
V	**SIG**	0.06		0.18		**SIG**	0.04		0.12	

B	**SIG**	0.04	0.12	**SIG**	0.03	0.09
V X B	**NS**	0.08	**-**	**SIG**	0.05	0.16

Table 4.Response of different Amaranthus types and planting systems on days to first harvest and number of harvestings under shade net conditions during *rabi* season.

	Days to first harvest					**Number of harvestings**				
	V_1	**V_2**	**V_3**	**V_4**	**MEAN**	**V_1**	**V_2**	**V_3**	**V_4**	**MEAN**
B_1	24.08	24.25	26.42	25.51	25.06	3.23	2.68	2.51	3.13	2.88
B_2	23.83	24.00	26.08	25.08	24.75	3.53	2.95	2.55	3.28	3.08
MEAN	23.95	24.12	26.25	25.30	24.91	3.38	2.81	2.53	3.20	2.98
	F-test	**S. Em (±)**		**CD @ 5%**		**F-test**	**S. Em (±)**		**CD @ 5%**	
V	**SIG**	0.07		0.22		**SIG**	0.03		0.07	
B	**SIG**	0.05		0.16		**SIG**	0.02		0.05	
V X B	**SIG**	0.11		0.33		**SIG**	0.03		0.12	

Table 5.Response of different Amaranthus types and planting systems on mean yield per square meter and mean Yield (ha^{-1}) **under shade net condition during *rabi* season.**

	Mean yield per square meter(kg)					**Mean Yield** ($t\ ha^{-1}$)				
	V_1	**V_2**	**V_3**	**V_4**	**MEAN**	**V_1**	**V_2**	**V_3**	**V_4**	**MEAN**
B_1	1.40	1.23	1.13	1.36	1.28	14.00	12.34	11.31	13.61	12.81
B_2	1.72	1.34	1.26	1.44	1.44	17.18	13.44	12.61	14.45	14.42
MEAN	1.56	1.29	1.20	1.40	1.36	15.59	12.89	11.96	14.03	13.61
	F-test	**S. Em (±)**		**CD @ 5%**		**F-test**	**S. Em (±)**		**CD @ 5%**	
V	**SIG**	0.03		0.09		**SIG**	0.13		0.39	
B	**SIG**	0.02		0.06		**SIG**	0.09		0.27	
V X B	**SIG**	0.04		0.012		**SIG**	0.19		0.57	

Table 6 Treatment details:

Factor A: Amaranthus types	**Factor B: Planting systems**
V_1: Konkan Durangi **V_2**: DPL-AS-6 **V_3**: DPL-AS-4 **V_4**: Nigadi Local	**B_1**: Flat bed **B_2**: Raised bed

Conclusion

Among the different varieties of Amaranthus, Konkan Durangi (V_1) grown under shade net conditions exhibited the shortest germination period, the greatest plant height, the highest number of leaves per plant, thicker stems, superior yield, and enhanced ascorbic acid and anthocyanin content compared to other Amaranthus varieties.

Among the various types of planting systems, raised beds demonstrated superior performance across all parameters (growth, yield, and quality) during the *rabi* season.

Planting Konkan Durangi on raised beds (V_1B_2) under shade net conditions resulted in the shortest time to germination and minimum days to first harvest, along with the tallest plants, highest leaf count per plant, thickest stems, most harvests, and the highest yield per square meter and per hectare. It also showed superior ascorbic acid and anthocyanin content.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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