Plant Archives Vol. 25, Supplement 2, 2025 pp.1825-1830 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-2.231

EFFECT OF MOISTURE STRESS ON GROWTH ATTRIBUTES OF CHIA (*SALVIA HISPANICA* L.) GENOTYPES

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(Date of Receiving : 08-05-2025; Date of Acceptance : 15-07-2025)

ABSTRACT

A pot experiment was conducted at College of Horticulture, Mudigere under protected condition to study the effect of moisture stress on performance of four local genotypes of chia *viz.,* H. D. Kote local, Mysore local, T. Narasipura local and Nanjangud local with three moisture stress levels *i.e.* 50, 75 and 100 % (Control) of field capacity. The experiment was laid out in a factorial completely randomized design with three replications. The results of the study inferred those different genotypes showed variable results on different attributes due to varying physiological constraints. Genotype H.D. Kote local showed better performance concerning growth attributes. While, the genotype Mysore local was found inferior. Severe water stress (50 % of FC) reduced the plant height (cm), number of leaves, number of branches, total fresh weight (g) and total dry matter (g/plant). Therefore, control (100 % of FC) was found beneficial for better growth of chia genotypes.
***Keywords*: Water stress, Field capacity, Genotype, Growth.**

Introduction

Chia (*Salvia hispanica* L.) is an annual herbaceous oilseed plant belonging to the Lamiaceae family, which is native from Southern Mexico and Northern Guatemala. It has been cultivated from tropical to subtropical regions. Chia is a dicotyledonous plant, approximately a meter tall, with opposite, petiolate and serrated leaves that are 4 to 8 cm long and 3 to 5 cm wide. The plant has ribbed and hairy quadrangular stems. The flowers are hermaphrodite and occur in numerous clusters in a spike protected by small bracts with long pointed tips. The fruit of chia is a schizocarp comprising of indehiscent locules that separate to form four fruitlets, referred to mericarps or nutlets. Commercially, each of these fruitlets is called 'seed', but actually, the (true) seed is contained within each fruitlet. The seeds are oval, smooth, shiny and their colour varies from black, gray and black spotted to white and size ranges from 1 mm to 2 mm (Ayerza and Coates, 2005). Chia crop is recognized as a superfood crop for its superior nutritional value. The seed has about 25-38 per cent oil by weight and it contains the highest proportion of α-linolenic acid (60 %) compared to other natural source known to date (Ayerza, 1995) and also higher levels of protein (19-23 %) in addition to other important nutritional components, such as vitamins, minerals and natural antioxidants (Coates and Ayerza, 1996).

India, which also remains high under the threat of malnutrition, has scarce commercial cultivation of chia crop and its consumption as well. Chia seeds are currently imported from countries like Australia, Bolivia and the US, which are sold at the rate of Rs. 2000 per kg in India. Currently, chia seed offers a huge potential in the industries of health, food, animal feed, pharmaceuticals, and nutraceuticals, due to its functional components (Mary, 2017). Though it is an introduced crop, area under cultivation of this crop is also gradually increasing in India while offering a potential and bright future to the Indian farmers and agro-markets. Studies on agronomic management of chia crop are limited as it is a newly introduced crop to

India and Karnataka in particular. In recent years, the cultivation of this crop has been started in Karnataka by the farmers of Mysore and Chamrajanagara districts under the technical guidance of the Central Food Technological Research Institute (CFTRI), Mysore.

In the changing climate scenario, plants are continuously subjected to several biotic and abiotic stresses. Among these stresses, drought is one of the most severe abiotic stresses which threaten crops production and yield. Crops undergo various morphological, physiological, biochemical, and molecular responses under water stress. Drought or water-limited situation triggers a wide variety of plant responses, ranging from cellular metabolism to changes in growth and development of roots, shoots, and ultimately yield.

Further, in recent times, water has become a scarce resource due to erratic rainfall and depleting groundwater resources in India as well as in Karnataka. Water stress is the main limiting environmental factor in most of the areas in the world (Valliyodan and Nguyen, 2006), and various investigations have been performed in several plant species. *Salvia hispanica* L. has been described as a species highly tolerant to water deficit, but in ecological-adaptive responses to water deficits are unknown (Silva *et al.,* 2018). As reports suggest that chia fairly responds to drought, the effect of different levels of moisture stress on the performance of this crop needs to be studied. So, the present investigation was planned to investigate the genetic potentiality of four local chia genotypes across three moisture stress levels.

Material and Methods

Experimental details

A pot experiment was carried out in the polyhouse of the Medicinal plants block, College of Horticulture, Mudigere. The study area lies between 130 08' to 130 53' Northern latitude and between 750 04' to 760 21' Eastern longitude and located at an altitude of 982 m above mean sea level. The experiment was laid out in a factorial completely randomized design with three replications. Treatment combinations were four genotypes *viz*., H. D. Kote local (V_1), Mysore local (V_2), T. Narasipura local (V_3) and Nanjangud local (V_4) with three levels of moisture stress *viz*., 50 % (S_1), 75 % (S_2) and 100 % (S_3 - Control) of field capacity. Thus, there were twelve treatment combinations *viz*., $T_1 = V_1S_1$, $T_2 = V_1S_2$, $T_3 = V_1S_3$, $T_4 = V_2S_1$, $T_5 = V_2S_2$, $T_6 = V_2S_3$, $T_7 = V_3S_1$, $T_8 = V_3S_2$, $T_9 = V_3S_3$, $T_{10} = V_4S_1$, $T_{11} = V_4S_2$ and $T_{12} = V_4S_3$.

Plant material and growing conditions

The seeds of chia genotypes were collected from respective localities within Mysore district of Karnataka. Seedlings were raised in the portrays with plugs filled with sterilized coco peat. The seedlings were ready for transplanting in 20 days from sowing. In the experiment, 288 plastic pots of 22 litres capacity and 32 cm depth were used. Red soil was sterilized with formalin and covered with black polythene cover for ten days. Soil, sand and FYM (Farm yard manure) were mixed in 2:1:1 ratio and filled in pot.

Three seedlings of 20 days old were transplanted to pots as per the treatment and plan of layout. Further, seedlings were immediately irrigated and drenched with bavistin at 0.2 per cent to avoid fungal diseases. Thinning was done at 12 days after transplanting retaining one plant per pot, so as to maintain optimum plant population. Irrigation was provided based on the condition of soil and crop, mainly at an interval of 3-4 days during the establishment period and later the interval was increased to 6-7 days up to 20 days of transplanting until all the seedlings reached 6 leaf stage. Moisture stress treatment was imposed to plants at 20 days after transplanting seedlings in pots. Weeding was done as and when necessary. All the plants of the given genotypes were harvested at 90 days after transplanting.

Measurements

Plant height (cm), number of leaves, number of branches, total fresh weight of plant (g) and total dry matter (g/plant) were recorded.

Growth parameters

Plant height (cm)

Plant height was measured from ground level to tip of the plant with measuring scale at 30, 60 and 90 days after transplanting.

Number of leaves per plant

The total number of leaves per plant was calculated by counting the number of individual leaves present in each plant at 30, 60 and 90 days after transplanting.

Number of branches per plant

Both primary and secondary branches were counted from each three plants and mean value was calculated and expressed as number of branches per plant.

Total fresh weight of plant (g)

The selected plant was uprooted and the whole plant was weighed using electric weighing balance and the weight was expressed in gram.

Total dry matter (g/plant)

The selected plants were uprooted and the whole plant was separated into leaves, stem and roots. The leaves, stem and roots were dried in hot air oven at 50 0C ± 5 0C for 72 hours. The oven dried parts were pooled and the total dry weight was recorded and expressed in gram per plant.

Statistical analysis

The data on morphological and physiological parameters collected from the experiment were subjected to statistical analysis by adopting Fisher's method of analysis of variance as outlined by Gomez and Gomez (1984). The level of significance used in the 'F' test was at 5 per cent. The critical difference (CD) values are given at 5 per cent level of significance, wherever the 'F' test was significant.

Results and Discussion

Different genotypes showed variable results on different attributes due to varying physiological constraints. Water stress caused a significant decrease in the plant height (cm), number of leaves, number of branches, total fresh weight (g) and total dry matter (g/plant) (Table 1 and Table 2). While, control (100% of FC) registered better growth attributes (Table 1 and Table 2).

The plant height, in all the stages of crop growth till harvest, was maximum in genotype H. D. Kote local (42.70 cm, 95.33 cm and 98.66 cm at 30 DAT, 60 DAT and 90 DAT respectively) at 100% of FC (control) and minimum in genotype Mysore local (26.93 cm, 75.75 cm and 85.54 cm at 30 DAT, 60 DAT and 90 DAT respectively) at stress of 50% of FC. The variation in the plant height might be due to the genetic makeup of different genotypes, their interaction with growing conditions, and their expression. Developmental morphology is inherent, but expression of a given genotype will vary in response to growing conditions (hence phenotypic plasticity) as reported by Srivastava, 2017. The above results were also found in agreement with Byari and Al-Rabighi (1996) in eggplant, Khaton *et al.* (2016) in sorghum, and Araghi *et al.* (2018) in *Mentha longifolia.*

The plant height was significantly influenced by different stress levels. Maximum plant height at all the stages of growth till harvest was recorded under control (100 % of FC) and minimum in higher stress level (50 % of FC). Thus, stress imposition showed a negative impact on the plant height. One of the first signs of water shortage is the decrease of turgor pressure and it results in the decrease of growth and development of cells especially in stem, the growth of cells is the most important process that is affected by water stress (Rhizopoulou and Diamantoglou, 1991). Similar observations were reported by Gershenzon *et al*. (1978) in *Satureja douglasii*, Misra and Srivastava (2000) in Japanese mint, Alishah *et al.* (2006) in *Ocimum basilicum*, Ardekani *et al.* (2007) in *Melissa officinalis* L., Belitz and Sams (2007) in *Silybum marianum* and Massoud *et al.* (2010) in *Majorana hortensis* Moench.

Maximum number of leaves per plant, in all the stages of crop growth till harvest was noticed in genotype H. D. Kote local (14.00, 41.50 and 31.80 at 30 DAT, 60 DAT and 90 DAT respectively) at 100% of FC (control) and minimum in genotype Mysore local (8.67, 30.73 and 20.20 at 30 DAT, 60 DAT and 90 DAT respectively) at stress of 50% of FC. The variation in the number of leaves might be due to the genetic makeup of different genotypes. The above results were found in agreement with Byari and Al-Rabighi (1996) in eggplant and Araghi *et al*. (2018) in *Mentha longifolia*.

The number of leaves per plant was significantly influenced by different stress levels. Maximum number of leaves at all the stages of growth till harvest was recorded under control (100 % of FC) and minimum in higher stress level (50 % of FC). Thus, stress imposition showed a negative impact on the number of leaves. The reduced number of leaves per plant may be due to limited availability of water, reduced turgor, and reduced cell division (Ahmed *et al*., 2016). When the leaf level decreases, the plant loses less water through transpiration. So, the restriction of leaf-level can be called the first mechanism against drought (Levitt, 1980). Similar observations were reported by Ahl *et al.* (2009) in *Melissa officinalis* L. and Chrysargyris *et al.* (2016) in lavender and sage.

Maximum number of branches in all the stages of crop growth till harvest was noticed in genotype H. D. Kote local (4.67, 9.83 and 12.55 at 30 DAT, 60 DAT and 90 DAT respectively) at 100% of FC (control) and minimum in genotype Mysore local (2.83, 7.83 and 10.33 at 30 DAT, 60 DAT and 90 DAT respectively) at stress of 50% of FC. The variation in the number of branches might be due to the genetic makeup of different genotypes and their interaction with growing conditions. The above results were found in agreement with Byari and Al-Rabighi (1996) in eggplant and Araghi *et al*. (2018) in *Mentha longifolia*.

The number of branches per plant was significantly influenced by different stress levels. Maximum number of branches at all the stages of growth till harvest was recorded under control (100 % of FC) and minimum in higher stress level (50 % of FC). The increase in leaf production may be attributed to more number of branches put forth by the plants under control. Thus, stress imposition showed a negative impact on the number of branches. The reduced number of branches per plant may be due to limited availability of moisture, limited availability of stem reservoirs, reduced internodes, reduced cell division, and low water potential as reported by Rauf *et al*. (2012). Similar observations were reported by Misra and Srivastava (2000) in Japanese mint and Ahl *et al*. (2016) in *Nepeta cataria*.

The total fresh weight, in all the stages of plant growth till harvest, was maximum in genotype H. D. Kote local (7.76 g, 18.38 g and 26.43 g at 30 DAT, 60 DAT and 90 DAT respectively) at 100% of FC (control) and minimum in genotype Mysore local (4.58 g, 15.84 g and 22.05 g at 30 DAT, 60 DAT and 90 DAT respectively) at stress of 50% of FC. The variation in the total fresh weight might be due to the genetic makeup of different genotypes and their interaction with growing conditions. The above results were found in agreement with Ahl *et al*. (2018) in *Thymus vulgaris*.

The total fresh weight was significantly influenced by different stress levels. Maximum total fresh weight at all the stages of growth till harvest was recorded under control (100 % of FC) and minimum in higher stress level (50 % of FC). Thus, stress imposition showed a negative impact on the total fresh weight. Water deficit conditions affect the water relations in plants and the water relation characteristics are most associated with cellular growth. Lesser availability of cell water decreases the cell water potential which in turn induces the turgidity losses. Thus, the elongation rate of differentiating cells is inhibited which ultimately leads to an overall reduction in biomass production (fresh and dry weight) as reported by Hsiao, 1973. Similar observations were reported by Misra and Srivastava (2000) in *Mentha arvensis* L., Khalid (2006) in Ocimum and Ahmed *et al*. (2016) in *Origanum vulgare* L. Reduction in fresh and dry weights of the plant may also be due to a decrease in plant growth, photosynthetic rate and canopy structure during the water stress as reported by Ayodele, 2001. A common adverse effect of water stress on plant growth and yield was the reduction in fresh and dry biomass production Bahreininejad *et al*. (2013).

The total dry matter, in all the stages of growth till harvest, was maximum in genotype H. D. Kote local (3.78 g/plant, 8.99 g/plant and 12.87 g/plant at 30 DAT, 60 DAT and 90 DAT respectively) at 100% of FC (control) and minimum in genotype Mysore local (2.08 g/plant, 7.72 g/plant and 10.58 g/plant at 30 DAT, 60 DAT and 90 DAT respectively) at stress of 50% of FC. The variation in the total dry weight might be due to the genetic potential of genotypes and their interaction with growing conditions. The above results were found in agreement with Ahl *et al*. (2018) in *Thymus vulgaris*.

The total dry matter was significantly influenced by different stress levels. Maximum total dry weight at all the stages of plant growth till harvest was recorded under control (100 % of FC) and minimum in higher stress level (50 % of FC). Thus, stress imposition showed a negative impact on the total dry weight. Lesser availability of water reduces the cell water potential which in turn induces turgidity losses and reduces cell division Thus, the elongation rate of differentiating cells is inhibited which ultimately leads to overall reduction in biomass production (fresh and dry weight) as reported by Hsiao, 1973. Lei *et al*. (2006) reported that drought stress inhibits the dry matter production largely through its inhibitory effects on leaf expansion, leaf development, and consequently reduced light interception. Similar observations were reported by Misra and Srivastava (2000) in *Mentha arvensis* L., Khalid (2006) in Ocimum and Ahmed *et al*. (2016) in *Origanum vulgare* L. Reduction in fresh and dry weights of the plant may also be due to a decrease in plant growth, photosynthesis and canopy structure during the water stress as reported by Ayodele, 2001. A common adverse effect of water stress on plant growth and yield was the reduction in fresh and dry biomass production Bahreininejad *et al*. (2013).

Conclusion

The results of the study inferred that different genotype showed variable results on different attributes due to varying physiological constraints. Genotype H. D. Kote local showed better performance concerning growth attributes. While, the genotype Mysore local was found inferior. Severe water stress (50 % of FC) reduced the plant height (cm), number of leaves, number of branches, total fresh weight (g) and total dry matter (g/plant). Therefore, it was concluded that, interaction of genotype H. D. Kote local and control (100 % of FC) was found beneficial for better plant growth among other interactions.

Table 1 : Effect of moisture stress on growth attributes (Plant height, No. of leaves and branches) in chia (*S. hispanica* L.) genotypes

Genotype	Moisture stress	Plant height (cm)			No. of leaves			No. of branches		
		30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
H. D. Kote local	50 % of FC	37.36	87.91	95.28	10.83	32.16	22.97	3.67	8.33	10.95
	75 % of FC	38.76	93.83	96.61	11.67	36.83	27.86	4.00	9.66	11.33
	100 % of FC	42.70	95.33	98.66	14.00	41.50	31.80	4.67	9.83	12.55
Mysore local	50 % of FC	26.93	75.75	85.54	8.67	30.73	20.20	2.83	7.83	10.33
	75 % of FC	28.73	79.83	88.08	9.83	34.66	24.47	3.17	8.83	10.41
	100 % of FC	32.62	82.16	91.30	11.50	35.11	28.13	3.83	9.50	10.66
T. Narasipura local	50 % of FC	31.53	77.16	89.00	10.50	32.33	21.93	3.17	8.66	10.55
	75 % of FC	33.56	82.50	94.16	12.00	34.66	25.43	3.33	9.16	11.08
	100 % of FC	37.50	83.33	95.21	12.67	36.50	29.86	3.67	9.33	11.16
Nanjangud local	50 % of FC	35.57	82.33	92.16	10.60	32.50	22.95	3.33	8.95	10.81
	75 % of FC	37.46	86.50	93.90	11.83	35.30	26.57	3.35	9.16	11.16
	100 % of FC	38.41	91.66	96.08	13.50	36.63	31.05	3.58	9.33	11.25
SEm ±		**1.25**	**0.61**	**0.56**	**0.61**	**0.54**	**0.19**	**0.23**	**0.20**	**0.15**
CD (P=0.05)		**NS**	**1.82**	**1.69**	**NS**	**1.63**	**0.58**	**NS**	**0.61**	**0.46**

FC = Field capacity; DAT = Days after transplanting; NS = Non-significant

Table 2 : Effect of moisture stress on growth attributes (Total fresh weight and Total dry matter) in chia (*S. hispanica* L.) genotypes

Genotype	Moisture stress	Total fresh weight of plant (g)			Total dry matter (g/plant)		
		30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
H. D. Kote local	50 % of FC	6.54	15.79	23.24	3.29	7.75	11.17
	75 % of FC	7.52	17.51	25.81	3.64	8.56	12.59
	100 % of FC	7.76	18.38	26.43	3.78	8.99	12.87
Mysore local	50 % of FC	4.58	15.84	22.05	2.08	7.72	10.58
	75 % of FC	4.74	16.05	22.75	2.18	7.82	10.93
	100 % of FC	5.14	16.39	23.14	2.37	8.00	11.12
T. Narasipura local	50 % of FC	6.42	16.06	23.11	3.00	7.85	11.04
	75 % of FC	6.60	16.40	23.39	3.05	8.00	11.26
	100 % of FC	7.34	16.66	23.62	3.40	8.08	11.35
Nanjangud local	50 % of FC	6.80	16.17	24.04	3.28	7.89	11.57
	75 % of FC	7.17	16.67	24.43	3.39	8.06	11.80
	100 % of FC	7.44	17.27	24.80	3.54	8.31	11.95
SEm ±		**0.20**	**0.12**	**0.33**	**0.07**	**0.05**	**0.17**
CD (P=0.05)		**NS**	**0.36**	**0.98**	**NS**	**0.17**	**0.51**

FC = Field capacity; DAT = Days after transplanting; NS = Non-significant

Acknowledgements

The authors are highly acknowledged to University of Agricultural and Horticultural Sciences, Shivamogga, for providing all the support required for this research work.

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