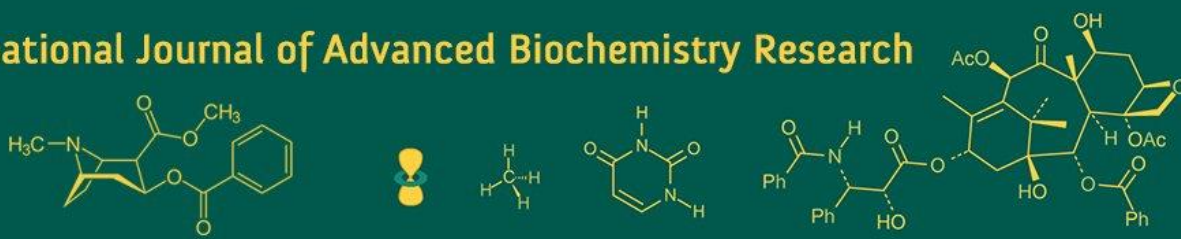


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Influence of NPK fertilization on dry matter partitioning in Chia (*Salvia hispanica* L.)

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Abstract

A field experiment was carried out during the *Rabi* season of 2025-26 at AICRP on Medicinal and Aromatic Plants and Betel vine, Nagarjuna Medicinal Plant Garden, Dr. Panjabrao Krishi Vidyapeeth Akola, Maharashtra, to study the influence of NPK fertilization on Dry matter Partitioning in Chia (*Salvia hispanica* L.). The experiment was laid out in RBD comprising eight treatments replicated thrice. The treatment include eight different NPK levels (kg ha^{-1}) i.e T₁ (Control), T₂ (20:10:10 kg NPK ha^{-1}), T₃ (30:15:15 kg NPK ha^{-1}), T₄ (40:20:20 kg NPK ha^{-1}), T₅ (50:25:25 kg NPK ha^{-1}), T₆ (60:30:30 kg NPK ha^{-1}), T₇ (70:35:35 kg NPK ha^{-1}), T₈ (80:40:40 kg NPK ha^{-1}).

The results showed that dry matter accumulation increased with increasing NPK levels, with T₇ (70:35:35 kg NPK ha^{-1}) recording the highest root, leaf, stem and total dry matter of 4.29, 8.67, 9.66 and 25.93 g plant⁻¹ at harvest, respectively. Treatment T₇ was at par with T₈ (80:40:40 kg NPK ha^{-1}) for dry matter of root, leaf and stem and total at harvest.

Keywords: Chia, NPK fertilization, dry matter partitioning, biomass accumulation

Introduction

Based on the present scenario, malnutrition remains a serious concern particularly in developing countries. One effective approach to address this issue is the promotion and adoption of underutilized “super crops” that are rich in essential nutrients such as vitamins, proteins, omega-3 fatty acids, dietary fibre, and minerals (Mary *et al.* 2018) [8]. Historical evidence indicates that Chia (*Salvia hispanica* L.) was widely used by ancient Mesoamerican civilizations, particularly the Aztecs and Mayans, for nutrition and medicinal purposes. It was considered as important crop next to beans in pre-Columbian societies (Ullah *et al.* 2016) [14]. The term “chia” or “chian” is derived from Spanish and refers to “oily” (Kulczyński *et al.* 2019) [5]. It is classified as a nutri-oilseed. Chia seeds contain about 30-40% oil out of which nearly 60% is omega-3 (α -linolenic acid). They are also a good source of protein (15-20%), fats (30-33%), carbohydrates (26-41%), dietary fibre (18-30%), ash (4-5%), along with minerals, vitamins and antioxidants. Due to this rich nutritional composition, chia is widely regarded as a nutraceutical and functional food. In addition to its nutritional benefits, it also plays a role in reducing the risk of several chronic diseases (Muñoz *et al.* 2013 and Prathyusha *et al.* 2019) [10, 11].

Currently Chia is cultivated in 16 nations and analysis of the global demand of chia indicates that in the future years the land area under chia will increase, as demand for omega-3 supplements is not completely fulfilled worldwide. Chia seeds also have the potential to meet the protein and fibre demands in coming future (Ayerza and Coates, 2011 and Silveria and Salas, 2014) [1]. The global demand of chia indicates that in the future years the land area under chia will increase, as demand for omega-3 supplements is not completely fulfilled worldwide. Chia has become increasingly popular as a dietary supplement, especially among individuals following vegetarian and gluten-free diets (Kamble *et al.* 2022) [6].

Chia (*Salvia hispanica* L.) is a promising emerging crop widely recognized as a “superfood” owing to its recognized health benefits.

It is an annual herbaceous plant belonging to the Lamiaceae family, originating from Mexico and Guatemala (Ixtaina *et al.* 2008) [3]. The plant can grow up to 1.5 m in height, and its seeds are the primary edible component (Karim *et al.* 2015) [4]. The seeds of Chia are small, oval-shaped and exhibit mottled colours such as brown, grey, black, and white.

Application of the macronutrients nitrogen, phosphorus and potassium is important for improving the growth and productivity of Chia. Among these, nitrogen is often the most critical, as it forms an essential component of nucleic acids, nucleotides, alkaloids, chlorophyll, phosphatides, enzymes and vitamins. As a result, it enhances water-use efficiency, increases resistance to environmental stresses, delays senescence, and prolongs the plant's lifespan. Phosphorus is involved in photosynthesis, acts as an energy carrier and helps to regulate the translocation of nutrients within the plant (Mengel *et al.* 2001) [7]. Potassium plays a crucial role in the synthesis of proteins and carbohydrates and facilitates the movement of sugars from leaves to seeds. It also acts as an activator of enzymes involved in photosynthesis. In addition, potassium helps regulate osmotic balance in plant cells, maintaining turgor pressure and thereby enhancing the plant's tolerance to stresses such as drought, frost, salinity, fungal infections, and diseases (Abd El-Daiem & El-Borhamy, 2015) [2]

The present study aims to standardize the optimal NPK fertilizer dose required for higher growth and biomass production of chia. This research seeks to provide a scientific basis for the inclusion of chia as a high-value, climate-resilient and nutritionally rich crop, thereby improving farmer's income and promoting sustainable agriculture in the region. The soils in this region, mainly medium to deep black soils, are often deficient in key nutrients, especially nitrogen and phosphorus. Application of an optimum NPK dose tailored to local soil and climatic conditions helps in optimizing nutrient uptake, leading to better growth and dry matter partitioning in Chia, being a relatively new crop in India, has high nutritional and economic value but its success depends on appropriate agronomic practices particularly nutrient management.

Materials and Methods

The present investigation was conducted during the *rabi* season of 2025-26 at AICRP on Medicinal And Aromatic Plants and Betelvine, Nagarjuna Medicinal Plant Garden, Dr PDKV, Akola which is situated at 20.675° N Latitude and 76.785° E Longitude. 307.42 meters above mean sea level in central (Vidarbha) agro-ecological zone of Maharashtra plateau. The soil of the experimental site was fine grained, clayey texture black cotton soils, having a neutral to moderately alkaline pH (7.81), medium in organic carbon (4.68 g kg⁻¹), low in available nitrogen (172.9 kg ha⁻¹), medium in available phosphorus (14.08 kg ha⁻¹) and high in available potassium (360.3 kg ha⁻¹). The weather conditions during the crop period were generally favourable for nutrient uptake and biomass development. At establishment (47th MW), the crop experienced 28.9°C maximum and 11.0°C minimum temperature, which supported early root growth. During vegetative growth (49-52 MW), temperatures of 28.0-29.2°C and 7.0-10.1 h sunshine provided suitable conditions for nutrient use and biomass accumulation. Flowering occurred under 28.8-34.0°C during 1-9 MW, favouring nutrient translocation and reproductive

growth. During seed filling (10-13 MW), temperatures rose to 35.6-39.3°C with 8.2-9.5 h sunshine, hastening maturity and highlighting the importance of adequate NPK supply before the late-season heat. The experiment was laid out in Randomized Block design (RBD) with eight treatments and three replications. The plot size was 5.40 cm x 4.50 cm in accordance with the treatment the seeds were sown during *Rabi* season 2025-26. The treatments were T₁(Control), T₂(20:10:10 kg NPK ha⁻¹), T₃(30:15:15 kg NPK ha⁻¹), T₄(40:20:20 kg NPK ha⁻¹), T₅(50:25:25 kg NPK ha⁻¹), T₆(60:30:30 kg NPK ha⁻¹), T₇(70:35:35 kg NPK ha⁻¹) and T₈(80:40:40 kg NPK ha⁻¹). In all treatments, 50 % N and full dose of P and K will be applied at the time of sowing and remaining 50 % dose of nitrogen will be applied at 35 days after sowing. Dry matter production was recorded at 30, 60, 90 DAS and at harvest. Total dry matter estimation was done by destructive sampling method. From net plot five plants were uprooted. The plants were separated into roots, stems and leaves, shade-dried for a few days and then oven-dried at 65°C until a constant weight was attained. The dry weights of all plant parts were recorded, summed to obtain the total dry matter plant⁻¹ and means of five plants expressed in g plant⁻¹.

Results and Discussion

The data on Dry matter partitioning (Root, leaf, stem and total) at various stages of crop growth (30, 60, 90 DAS and at harvest) as influenced by different treatments are presented in Table 1 and 2.

Root Dry Matter (g plant⁻¹)

The data revealed that different NPK levels significantly influenced root dry matter at all periodical observations. Root dry matter accumulation increased progressively with crop growth from 30 DAS to 90 DAS under all NPK treatments.

The root dry matter was increased significantly with 70:35:35 kg NPK ha⁻¹ (T₇) among the all treatments attaining a maximum of 4.29 g plant⁻¹ at harvest was at par with 80:40:40 kg NPK ha⁻¹ (T₈) with 4.26 g plant⁻¹. The lowest values were observed under Control (T₁) with 3.01 g plant⁻¹. The higher root dry matter under 70:35:35 kg NPK ha⁻¹ may be associated with improved nutrient availability and root growth

Leaf Dry Matter (g plant⁻¹)

Leaf dry matter was significantly affected by the different NPK treatments at all periodical observations. Among the treatments, 70:35:35 kg NPK ha⁻¹ T₇) consistently produced the highest leaf dry matter with 8.67 g plant⁻¹ at harvest, being at par with 80:40:40 kg NPK ha⁻¹ T₈ - 8.27g plant⁻¹. While, control treatment T₁ recorded lowest leaf dry matter with 5.24 g plant⁻¹ at harvest. The enhanced leaf biomass under T₇ was attributed to the readily availability of balanced nutrients, which stimulated vigorous vegetative growth and greater photosynthetic activity.

Stem Dry Matter (g plant⁻¹)

The Stem dry matter presented significant variation with different NPK Levels at all periodical observations. The application of 70:35:35 Kg NPK ha⁻¹ intreatment T₇ produced the significantly higher stem biomass throughout the crop period reaching 9.66 g plant⁻¹ at harvest which was statistically at par with application of 80:40:40 kg NPK ha⁻¹

¹T₈ with 9.32 g plant⁻¹. The increased biomass in T₇ is due to enhanced nutrient availability, which promotes stem elongation and thickening.

Total dry matter (g plant⁻¹)

The total dry matter partitioning of chia was significantly influenced by different NPK levels at all growth stages (30, 60, 90 DAS and at harvest). Total dry matter increased progressively with crop age under all treatments. The general mean total dry matter increased from 3.95 g plant⁻¹ at 30 DAS to 22.39 g plant⁻¹ at harvest.

At 30 DAS, the highest total dry matter was recorded with 4.65 g plant⁻¹ under T₇ (70:35:35 kg NPK ha⁻¹) which was significantly superior to the remaining treatments while the lowest value was observed in the Control (T₁) with 3.59 g plant⁻¹.

A similar pattern was observed at 60 DAS, where T₈ produced the highest dry matter (10.34 g plant⁻¹) which was at par with T₇ with (9.89 g plant⁻¹) and T₆ (8.86 g plant⁻¹). At 90 DAS, the maximum total dry matter was recorded under T₇ with 17.31 g plant⁻¹ remained statistically at par with T₈ which has 16.66 g plant⁻¹ and T₆ with 14.49 g plant⁻¹, whereas, the control treatment has 9.63 g plant⁻¹. At harvest,

T₇ recorded the highest total dry matter 25.93 g plant⁻¹, which was statistically at par with T₈ has 25.80 g plant⁻¹. The lowest total dry matter at harvest was observed under the control (T₁) was 17.03 g plant⁻¹.

The application of 70:35:35 NPK kg ha⁻¹ resulted in the highest accumulation of leaf, stem and root dry matter plant⁻¹ at harvest, Total plant dry matter steadily increased until harvest. However, plants receiving optimal fertilizer doses leading to greater dry matter accumulation compared to those with lower fertilizer levels. The improved dry matter production at higher fertilizer levels was attributed to enhanced nutrient availability and metabolite supply, supporting both vegetative growth and reproductive development. Similar results were also reported by Mohanty *et al.* (2022) [9], who observed in chia that increased dry matter production with higher nitrogen levels owing to improved nutrient availability and photosynthetic efficiency. Similarly Singh *et al.* (2023) [13] reported in chia that application of 80:60:60 kg NPK ha⁻¹ resulted higher dry matter accumulation as compared with lower fertilizer levels. The higher dry matter accumulation was associated with greater plant height, number of leaves and primary and secondary branches.

Table 1: Effect of different NPK levels on Dry matter partitioning at 30 and 60 DAS in chia

Treatments	Dry matter partitioning (g)							
	30 DAS				60 DAS			
	Root	Leaves	Stem	Total	Root	Leaves	Stem	Total
T1	1.13	1.27	1.18	3.59	1.36	2.04	1.56	4.79
T2	1.16	1.29	1.21	3.66	1.32	2.26	1.94	5.56
T3	1.17	1.31	1.22	3.71	1.51	2.73	2.11	6.87
T4	1.19	1.32	1.25	3.76	1.75	2.87	2.22	7.44
T5	1.22	1.33	1.28	3.89	1.87	2.89	2.34	8.05
T6	1.25	1.34	1.27	4.15	2.12	3.28	2.73	8.86
T7	1.29	1.37	1.32	4.65	2.33	4.27	3.75	9.89
T8	1.28	1.36	1.29	4.19	2.14	4.14	3.36	10.34
SE (m) +	0.03	0.02	0.02	0.21	0.23	0.46	0.29	0.50
CD at 5%	0.10	0.09	0.08	0.65	0.69	1.41	0.88	1.53

Table 2: Effect of different NPK levels on Dry matter partitioning at 90 DAS and at harvest in chia

Treatments	Dry matter partitioning (g)							
	90 DAS				At harvest			
	Root	Leaves	Stem	Total	Root	Leaves	Stem	Total
T1	2.43	3.26	3.74	9.63	3.01	4.89	6.25	17.03
T2	2.51	3.68	3.87	10.56	3.11	5.24	6.99	18.03
T3	2.81	3.74	4.26	11.04	3.55	6.04	7.65	21.17
T4	2.83	4.41	4.34	12.15	3.81	6.81	8.78	23.95
T5	3.01	4.99	5.03	13.39	3.96	7.14	9.11	22.78
T6	3.04	5.32	5.99	14.49	4.09	7.55	9.23	24.41
T7	3.97	7.58	7.69	17.31	4.29	8.67	9.66	25.93
T8	3.88	6.44	6.22	16.66	4.26	8.27	9.32	25.80
SE (m) +	0.30	0.43	0.54	0.55	0.27	0.47	0.33	0.53
CD at 5%	0.92	1.31	1.65	1.67	0.82	1.43	1.00	1.60

Conclusion

The present investigation showed that NPK application markedly influenced dry matter partitioning in chia. Among the nutrient levels evaluated, application of 70:35:35 kg NPK ha⁻¹ was superior for overall dry matter production and partitioning and was generally comparable with application of 80:40:40 kg NPK ha⁻¹ for several components.

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