International Journal of Environment, Agriculture and Biotechnology
Vol-10, Issue-3; May-Jun, 2025
Peer-Reviewed International Journal
Journal Home Page Available: https://ijeab.com/
Journal DOI: 10.22161/ijeab

Impact of Different Nitrogen Sources and Plant Spacing on the Growth Characteristics of Kalmegh (*Andrographis paniculata* Nees) under the Malwa Agro-Climatic Region of Madhya Pradesh

Sunil Bhakar[1], Dhanraj Choudhyary [2] and Kan Singh [3]

[1]Research Scholar, Department of Plantation, Spices, Medicinal and Aromatic Crops College of Horticulture, Mandsaur, (458001) Madhya Pradesh
[2]Research Scholar, Department of Horticulture, College of Agriculture, RVSKVV, Gwalior (M.P.)
[3]Research Scholar, Department of Horticulture (Floriculture, Landscape and Architecture), College of Agriculture Horticulture, Mandsaur, (458001) Madhya Pradesh
*Corresponding Author Email: Sunilbhakar784@gmail.com

Received: 04 Apr 2025; Received in revised form: 05 May 2025; Accepted: 13 May 2025; Available online: 17 May 2025

Abstract— *A field experiment titled "Effect of Nitrogen Sources and Plant Geometry on Herbage Yield and Nutrient Uptake in Kalmegh (Andrographis paniculata Nees.) under the Malwa Plateau of Madhya Pradesh" was conducted during the Kharif season of 2024–25. The study was undertaken at the Herbal Garden, Department of Plantation, Spices, Medicinal and Aromatic Crops, KNK College of Horticulture, Mandsaur (M.P.). Observations on various growth parameters were systematically recorded using established scientific methodologies. The study assessed key growth parameters, including Leaf Area (cm² plant⁻¹) Fresh weight (g plant⁻¹) and Dry weight (g plant⁻¹). Observations were recorded from five randomly selected plants at intervals of 30, 60, 90, and 120 days after transplanting (DAT), as well as at the time of harvest. The results indicated that among the nitrogen treatments,* N_1 *(40 kg N through vermicompost + 40 kg N through urea) showed the highest values for leaf area (8.75, 45.10, 104.54, 134.45, and 134.37 cm²), fresh weight (9.13, 25.51, 45.00, 64.41, and 63.72 g), and dry weight (2.68, 6.81, 23.06, 41.77, and 44.17 g). In terms of plant spacing, the* S_1 *geometry (20 × 10 cm) resulted in the greatest leaf area (9.12, 45.80, 105.33, 135.12, and 134.43 cm²), fresh weight (9.22, 26.70, 45.15, 64.95, and 64.34 g), and dry weight (2.76, 6.92, 22.98, 41.70, and 44.22 g). Furthermore, the combined treatment of* $S_1 \times N_1$ *produced the most significant results, with maximum leaf area (10.82, 48.23, 108.83, 139.01, and 137.53 cm²), fresh weight (10.50, 32.49, 48.83, 68.50, and 70.06 g), and dry weight (3.49, 8.54, 28.68, 46.61, and 47.79 g) at 30, 60, 90 DAT, and at harvest.*

Keywords— **Kalmegh, nitrogen sources, plant spacing, leaf area, biomass production**

I. INTRODUCTION

Kalmegh (*Andrographis paniculata*), a significant medicinal plant from the Acanthaceae family, holds a prominent place in traditional and modern herbal medicine. The *Andrographis* genus, native to India, comprises around 40 species globally, with 19 found in India. Among these, only *A. paniculata* and *A. alata* are recognized for their distinct medicinal properties (Farooqi et al., 2010). Kalmegh is an herbaceous annual plant that can reach a height of up to 110 cm. Recognizing its therapeutic importance, the National Medicinal Plant Board has listed Kalmegh 17th among 32 prioritized medicinal species (NMPB, 2014). It plays a crucial role in Indian pharmacopoeia and features in 26 Ayurvedic formulations (Verma *et al.*, 2018). Kalmegh is the key ingredient in "Alui," a traditional remedy widely used in West Bengal to treat dyspepsia and general weakness in both adults and children. Known for its potent antipyretic and antiviral properties, Kalmegh has even been cited as a potential aid in combating COVID-19 (Verma *et al*., 2021). Its therapeutic uses extend across China, India, and other Southeast Asian countries, where it is employed in treating ailments like fever, colds, laryngitis, malaria, dysentery, and diarrhea. The plant also exhibits antibacterial, anti-inflammatory, antithrombotic, and immune-boosting effects (Verma *et al*., 2024). As the demand for herbal medicines and health supplements continues to rise, there is a growing emphasis on cultivating medicinal plants that are safe, high in quality, and free from harmful chemicals. Consequently, reducing chemical inputs in Kalmegh cultivation is critical, with a shift toward organic practices gaining momentum. Organic liquid manures and bioformulations offer safer, eco-friendly alternatives, making them ideal for a plant used in both Ayurvedic and pharmaceutical applications. Furthermore, the use of organic inputs and microbial inoculants not only improves fertilizer efficiency but also enhances soil health by improving its physicochemical and biological properties (Trisilawati *et al*., 2019). Nitrogen is especially vital for Kalmegh, as it supports chlorophyll production, protein synthesis, and overall vegetative growth, which directly impacts the development of leaves and stems—the main reservoirs of its key bioactive compound, andrographolide (Kumar *et al*., 2018; Verma *et al*., 2024). Proper nitrogen nutrition contributes to increased biomass and better yields, but a balanced approach is essential. Over-application may lead to lush vegetative growth at the cost of reduced medicinal quality. Thus, efficient nitrogen management is crucial for optimizing both yield and therapeutic efficacy (Shakywa *et al*., 2022; Pandey *et al*., 2025). Given the increasing demand for herbal products across global pharmaceutical and Ayurvedic sectors, Kalmegh is poised to become a highly valuable crop. In light of this, the present study has been designed to explore the plant's response to various nitrogen sources and application methods, as these factors play a significant role in influencing its growth, yield, and medicinal quality (Sharangi *et al*., 2025).

II. MATERIALS AND METHODS

Experimental site and soil: The field experiment was conducted during the Kharif season of 2024–2025 at the Herbal Garden, Department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Mandsaur, which operates under Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.). The experimental site is located on the Malwa Plateau in the western region of Madhya Pradesh, positioned between 23.45° to 24.13° North latitude and 74.44° to 75.18° East longitude, at an elevation of 435 meters above mean sea level. This area falls within Agro-Climatic Zone 9 of the state. Prior to fertilizer application, soil samples were collected from a depth of 10–15 cm at various points across the field using standard sampling techniques. These samples were combined to form a representative composite sample through thorough mixing. Soil analysis revealed a light black, loamy texture with low levels of available nitrogen and phosphorus but high potassium content.

Experimental design and treatments: The experiment was laid out using a Factorial Randomized Block Design (FRBD) and replicated three times. Each individual plot measured 4.32 m² (3.60 m × 1.20 m), while the total experimental area covered 399.43 m² (14.96 m × 26.70 m). The study included two factors: plant geometry as the main plot treatment with four spacings — S_1: 20 × 10 cm, S_2: 20 × 15 cm, S_3: 20 × 20 cm, and S_4: 30 × 10 cm; and nitrogen sources as subplot treatments with four levels — N_1: 40 kg N from vermicompost + 40 kg N from urea, N_2: 60 kg N from vermicompost + 20 kg N from urea, N_3: 80 kg N from vermicompost, and N_4: recommended dose of fertilizers (RDF) consisting of 80 kg/ha N, 30 kg/ha P, and 50 kg/ha K. A total of 16 treatment combinations resulting from the interaction of these factors were evaluated.

Observations recorded: Growth parameter observations were recorded using standardized procedures. The primary parameters assessed included leaf area (cm² per plant), fresh weight (g per plant), and dry weight (g per plant). For each treatment, five plants were randomly selected and measurements were taken at 30, 60, 90, and 120 days after transplanting (DAT), as well as at harvest. Leaves were detached from the sampled plants and their area was measured using a leaf area meter (LAM 211), with results expressed in cm² per plant for each observation stage. The entire fresh herb from each labeled plant was harvested and weighed using an electronic balance, with the average calculated and recorded in grams per plant. For dry weight determination, the harvested herbs from five tagged plants were dried in a hot air oven at 65°C until a constant weight was achieved, then weighed with an electronic balance and expressed as the mean dry weight in grams. All measurements were taken from the net plot area for each treatment. The collected data were subjected to analysis of variance (ANOVA) following the method described by Panse and Sukhatme (1985).

Statistical analysis: The data recorded for different parameters were analyzed with the help of analysis of variance (ANOVA) technique for a randomized block design. The results are presented at 5% level of significance (P=0.05).

III. RESULTS AND DISCUSSION

Morphological parameters

Leaf area (cm^2) at 30, 60, 90, 120 DAT and at harvest

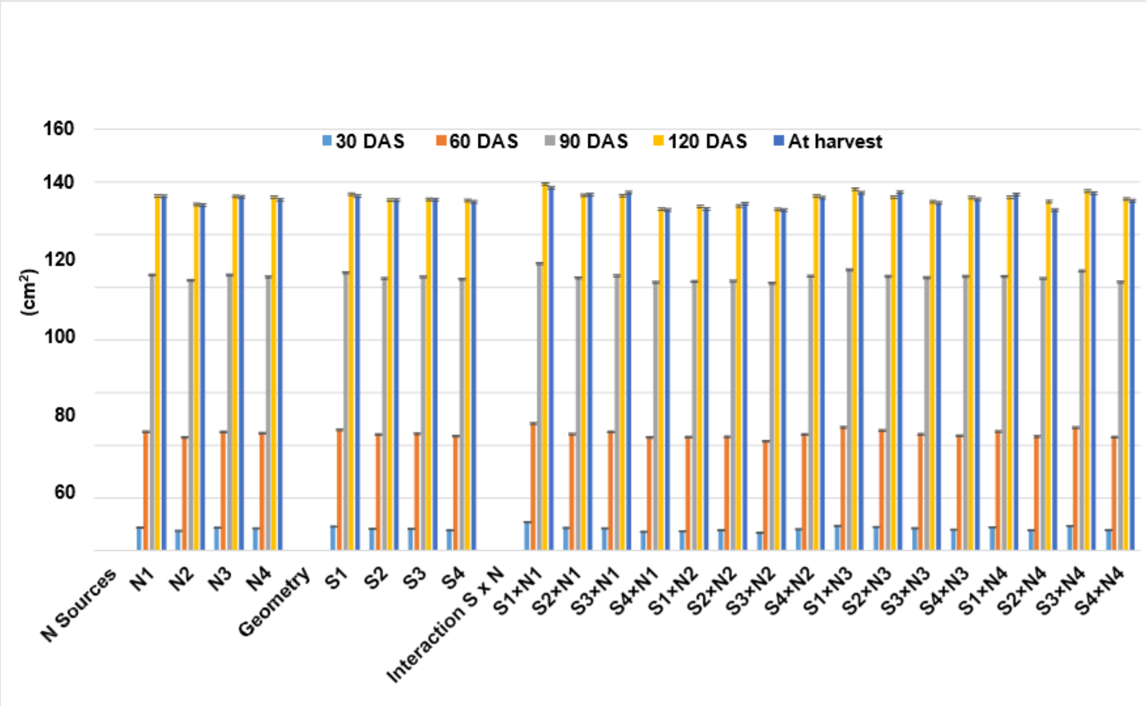
The leaf area of the Kalmegh plant was significantly affected by the application of nitrogen, the different planting geometries, and their combined interactions at various stages of growth (30, 60, 90, and 120 days after transplanting (DAT), as well as at harvest). This is clearly demonstrated in Table 1 and Fig. 1, which highlight the variations observed in leaf area across these factors. At 30 days after transplanting (DAT), among the different planting geometries, the highest leaf area was observed in S_1 (20 × 10 cm) with 9.12 cm², followed by S_3 (20 × 20 cm) at 8.28 cm², and S_2 (20 × 15 cm) at 8.27 cm², while the lowest was recorded in S_4 (30 × 10 cm) with 7.75 cm². In terms of nitrogen sources, N_1 (40 kg N from vermicompost + 40 kg N from urea) showed the maximum leaf area of 8.75 cm², closely followed by N_3 (80 kg N from vermicompost) at 8.71 cm², while N_2 (60 kg N from vermicompost + 20 kg N from urea) recorded the lowest at 7.51 cm². The interaction between planting geometry and nitrogen sources was significant, with $S_1 \times N_1$ producing the highest leaf area of 10.82 cm², and the lowest recorded in $S_4 \times N_1$ at 7.12 cm². At 60 DAT, S_1 (20 × 10 cm) again showed the highest leaf area (45.80 cm²), followed by S3 (44.31 cm²) and S2 (44.06 cm²), with S4 recording the lowest (43.42 cm²). Among nitrogen treatments, N_1 again led with 45.10 cm², followed closely by N_3 (45.01 cm²), and the lowest was seen in N_2 (42.94 cm²). The $S_1 \times N_1$ combination produced the highest leaf area (48.23 cm²), while $S_3 \times N_2$ showed the lowest (41.44 cm²). At 90 DAT, the trend continued, with S1 leading in leaf area (105.33 cm²), followed by S_3 (103.80 cm²) and S_2 (103.22 cm²), and S4 being the lowest (102.91 cm²). N_1 and N_3 again recorded the highest values (104.54 and 104.48 cm², respectively), and N_2 the lowest (102.46 cm²). The interaction $S_1 \times N_1$ recorded the maximum (108.83 cm²), followed by $S_1 \times N_3$ (106.45 cm²) and $S_3 \times N_4$ (106.05 cm²). The lowest was observed in $S_3 \times N_2$ (101.41 cm²). At 120 DAT, S_1 (135.12 cm²) maintained the highest leaf area, followed by S3 (133.15 cm²) and S_2 (132.93 cm²), with S_4 again the lowest (132.78 cm²). Among nitrogen sources, N_1 remained highest (134.45 cm²), with N_3 close behind (134.30 cm²) and N_2 lowest (131.26 cm²). The $S_1 \times N_1$ interaction yielded the maximum leaf area (139.01 cm²), followed by $S_1 \times N_3$ (137.04 cm²) and $S_3 \times N_4$ (136.33 cm²). The lowest was in $S_3 \times N_2$ (129.40 cm²). At harvest, S_1 again recorded the highest leaf area (134.43 cm²), followed by S_3 (133.04 cm²) and S_2 (132.87 cm²), with S_4 being the lowest (132.22 cm²). N_1 resulted in the highest leaf area (134.37 cm²), followed by N_3 (134.14 cm²) and N_2 (131.00 cm²) as the lowest. The $S_1 \times N_1$ treatment remained the top performer (137.53 cm²), followed by $S_2 \times N_3$ (135.88 cm²) and $S_3 \times N_1$ (135.77 cm²). The lowest values were noted in $S_4 \times N_2$ and $S_2 \times N_4$ (both 129.10 cm²). The results show that nitrogen application influenced leaf area positively, with treatments involving higher nitrogen doses generally leading to larger leaf areas. Similarly, the planting geometry also played a crucial role in determining leaf area, with certain spacing configurations leading to better leaf expansion. The interaction between nitrogen sources and planting geometry further impacted the growth, producing varying results at different growth stages. At each observation point, the combination of these factors resulted in a significant variation in leaf area, underscoring the importance of optimizing both nitrogen levels and planting geometry for maximum growth potential in Kalmegh cultivation.These results align with findings by Sadashiv *et al.* (2007), who reported that vermicompost application enhanced plant height, branching, and leaf area in Coleus (*Coleus forskohlii*). Similarly, Kumar *et al.* (2018) attributed increased leaf expansion to higher nitrogen uptake and availability, supporting the outcomes observed in this study.

Table 1:- Effect of nitrogen sources, planting geometries, and their interactions on leaf area (cm^2) at various growth stages in Kalmegh.

Treatments		30 DAT	60 DAT	90 DAT	120 DAT	At harvest
N Sources						
N1	**40kg N by vermi +40 kg N by Urea**	8.75	45.10	104.54	134.45	134.37
N2	**60kg N by vermi +20 kg N by Urea**	7.51	42.94	102.46	131.26	131.00
N3	**80 kg N by Vermi**	8.71	45.01	104.48	134.30	134.14
N4	**RDF**	8.45	44.55	103.78	133.98	133.07
S.Em ±		**0.22**	**0.48**	**0.38**	**0.64**	**0.22**

CD at 5%		**0.64**	**1.40**	**1.09**	**1.86**	**0.64**
Geometry						
S1	**20 X 10 cm**	9.12	45.80	105.33	135.12	134.43
S2	**20 X 15 cm**	8.27	44.06	103.22	132.93	132.87
S3	**20 X 20 cm**	8.28	44.31	103.80	133.15	133.04
S4	**30 X 10 cm**	7.75	43.42	102.91	132.78	132.22
S.Em ±		**0.22**	**0.48**	**0.38**	**0.64**	**0.22**
CD at 5%		**0.64**	**1.40**	**1.09**	**1.86**	**0.64**
Interaction S (Geometry) x N (Sources)						
S1×N1		10.82	48.23	108.83	139.01	137.53
S2×N1		8.59	44.18	103.37	134.73	134.99
S3×N1		8.47	45.07	104.23	134.59	135.77
S4×N1		7.12	42.93	101.71	129.47	129.20
S1×N2		7.41	43.07	102.09	130.48	129.54
S2×N2		7.76	43.17	102.25	130.68	131.53
S3×N2		6.78	41.44	101.41	129.40	129.10
S4×N2		8.08	44.08	104.10	134.47	133.81
S1×N3		9.40	46.73	106.45	137.04	135.67
S2×N3		8.97	45.60	104.00	134.00	135.88
S3×N3		8.50	44.10	103.50	132.28	131.80
S4×N3		7.98	43.60	103.98	133.86	133.21
S1×N4		8.85	45.18	103.97	133.94	135.00
S2×N4		7.75	43.30	103.24	132.30	129.10
S3×N4		9.38	46.64	106.05	136.33	135.51
S4×N4		7.82	43.07	101.84	133.34	132.66
S.Em ±		**0.44**	**0.97**	**0.75**	**1.29**	**0.45**
CD at 5%		**1.28**	**2.80**	**2.18**	**3.72**	**1.29**

ISSN: 2456-1878 (Int. J. Environ. Agric. Biotech.)
https://dx.doi.org/10.22161/ijeab.103.11



.

Fig.- 1 Effect of nitrogen sources, planting geometries, and their interactions on leaf area (cm^2) at various growth stages in Kalmegh.

Fresh weight (g plant^{-1}) at 30, 60, 90, 120 DAT and at harvest

The fresh weight of Kalmegh plants was significantly influenced by the nitrogen sources, planting geometries, and their interactions at different growth stages (30, 60, 90, 120 DAT, and at harvest), as shown in Table 2 and depicted in Fig. 2. **At 30 DAT**, the highest fresh weight was observed in the S_1-20 x 10 cm planting geometry (9.22 g), followed by S_3-20 x 20 cm (8.72 g) and S_2-20 x 15 cm (8.32 g). The lowest fresh weight was recorded in S_4-30 x 10 cm (8.21 g). Among the nitrogen treatments, the highest fresh weight (9.13 g) was achieved with N_1, which provided 40 kg N through vermicompost + 40 kg N through urea. N_3, which supplied 80 kg N through vermicompost, followed closely with 9.00 g. The lowest fresh weight (7.94 g) was seen with N_2 (60 kg N through vermicompost + 20 kg N through urea). The interaction between planting geometry and nitrogen sources showed significant variation, with the $S_1 \times N_1$ combination producing the highest fresh weight (10.50 g), followed by $S_3 \times N_3$ (9.55 g). The lowest fresh weight was observed in $S_3 \times N_2$ (6.89 g). **At 60 DAT**, the highest fresh weight was recorded in S_1-20 x 10 cm (26.70 g), followed by S_3-20 x 20 cm (22.98 g) and S_2-20 x 15 cm (22.00 g), with the lowest observed in S_4-30 x 10 cm (20.93 g). Among nitrogen sources, N_1 again produced the highest fresh weight (25.51 g), closely followed by N_3 (24.75 g). The lowest fresh weight was observed with N2 (19.47 g). The $S_1 \times N_1$ interaction produced the highest fresh weight (32.49 g), followed by $S_1 \times N_3$ (30.54 g). The lowest was recorded in $S_2 \times N_4$ (18.14 g). **At 90 DAT**, the highest fresh weight was again observed in S_1-20 x 10 cm (45.15 g), followed by S_3-20 x 20 cm (44.13 g) and S_2-20 x 15 cm (42.60 g), with the lowest in S_4-30 x 10 cm (41.50 g). Nitrogen treatments showed similar trends, with N_1 (45.00 g) and N_3 (44.60 g) producing the highest fresh weight, while N_2 (39.76 g) showed the lowest. The interaction effects showed significant variation, with $S_3 \times N_1$ producing the highest fresh weight (49.54 g), followed by $S_1 \times N_1$ (48.83 g). The lowest was recorded in $S_4 \times N_1$ (38.66 g). **At 120 DAT**, the highest fresh weight was recorded in S_1-20 x 10 cm (64.95 g), followed by S_3-20 x 20 cm (63.54 g) and S_2-20 x 15 cm (62.60 g), with the lowest in S4-30 x 10 cm (62.04 g). Among nitrogen sources, N_1 (64.41 g) and N_3 (64.21 g) recorded the highest fresh weight, while N_2 (61.14 g) had the lowest. The interaction effects showed significant variation, with $S_1 \times N_1$ producing the highest fresh weight (68.50 g), followed by $S_1 \times N_3$ (68.25 g). The lowest was observed in $S_4 \times N_1$ (60.01 g). **At harvest**, S_1-20 x 10 cm again recorded the highest fresh weight (64.34 g), followed by S_3-20 x 20 cm (62.07 g) and S_2-20 x 15 cm (61.77 g), with the lowest in S_4-30 x 10 cm (60.17 g). For nitrogen sources, N_1 (63.72 g) and N_3 (63.27 g) gave the highest fresh weight, while N_2 (59.17 g) had the lowest. The $S_1 \times N_1$ combination again produced the highest fresh weight (70.06 g), followed by $S_3 \times$ N4 (65.66 g) and $S_1 \times N_3$ (66.94 g). The lowest was observed in $S_4 \times N_2$ (57.79 g). The increased fresh weight observed in these treatments can be attributed to enhanced photosynthetic activity, leading to greater nutrient uptake and higher dry biomass accumulation throughout the plant's growth cycle. These findings are in line with similar studies by (Harisha *et al*., 2010) on garden cress and (Hemalatha *et al*., 2010) on Kalmegh, where the application of appropriate nitrogen doses was found to support improved growth and biomass production.

Table 2:- Effect of N sources, planting geometries, and their interactions on fresh weight (g plant^{-1}) at various growth stages in Kalmegh.

Treatments		30 DAT	60 DAT	90 DAT	120 DAT	At harvest
N Sources						
N_1	**40kg N by vermi +40 kg N by Urea**	9.13	25.51	45.00	64.41	63.72
N_2	**60kg N by vermi +20 kg N by Urea**	7.94	19.47	39.76	61.14	59.17
N_3	**80 kg N by Vermi**	9.00	24.75	44.60	64.21	63.27
N_4	**RDF**	8.41	22.86	44.02	63.37	62.18
S.Em ±		**0.18**	**0.85**	**1.01**	**0.99**	**0.85**
CD at 5%		**0.53**	**2.45**	**2.90**	**2.87**	**2.44**
Geometry						
S_1	**20 X 10 cm**	9.22	26.70	45.15	64.95	64.34
S_2	**20 X 15 cm**	8.32	22.00	42.60	62.60	61.77
S_3	**20 X 20 cm**	8.72	22.98	44.13	63.54	62.07
S_4	**30 X 10 cm**	8.21	20.93	41.50	62.04	60.17
S.Em ±		**0.18**	**0.85**	**1.01**	**0.99**	**0.85**
CD at 5%		**0.53**	**2.45**	**2.90**	**2.87**	**2.44**
Interaction S (Geometry) x N (Sources)						
$S_1 \times N_1$		10.50	32.49	48.83	68.50	70.06
$S_2 \times N_1$		9.01	24.16	42.95	63.96	62.62
$S_3 \times N_1$		9.27	26.54	49.54	65.17	64.17
$S_4 \times N_1$		7.72	18.87	38.66	60.01	58.01
$S_1 \times N_2$		8.09	18.91	38.72	60.19	58.63
$S_2 \times N_2$		8.31	19.47	39.39	60.66	58.68
$S_3 \times N_2$		6.89	17.70	38.35	59.24	56.25
$S_4 \times N_2$		8.47	21.81	42.60	64.46	63.13
$S_1 \times N_3$		9.35	30.54	48.73	68.25	66.94
$S_2 \times N_3$		8.66	26.22	45.37	64.34	62.22
$S_3 \times N_3$		9.55	19.91	40.60	61.52	62.20
$S_4 \times N_3$		8.42	22.33	43.70	62.73	61.73
$S_1 \times N_4$		8.94	24.84	44.32	62.86	61.71
$S_2 \times N_4$		7.30	18.14	42.67	61.46	63.55

$S_3 \times N_4$	9.17	27.77	48.04	68.23	65.66
$S_4 \times N_4$	8.23	20.69	41.04	60.95	57.79
S.Em ±	**0.36**	**1.69**	**2.01**	**1.99**	**1.69**
CD at 5%	**1.05**	**4.89**	**5.81**	**5.73**	**4.88**

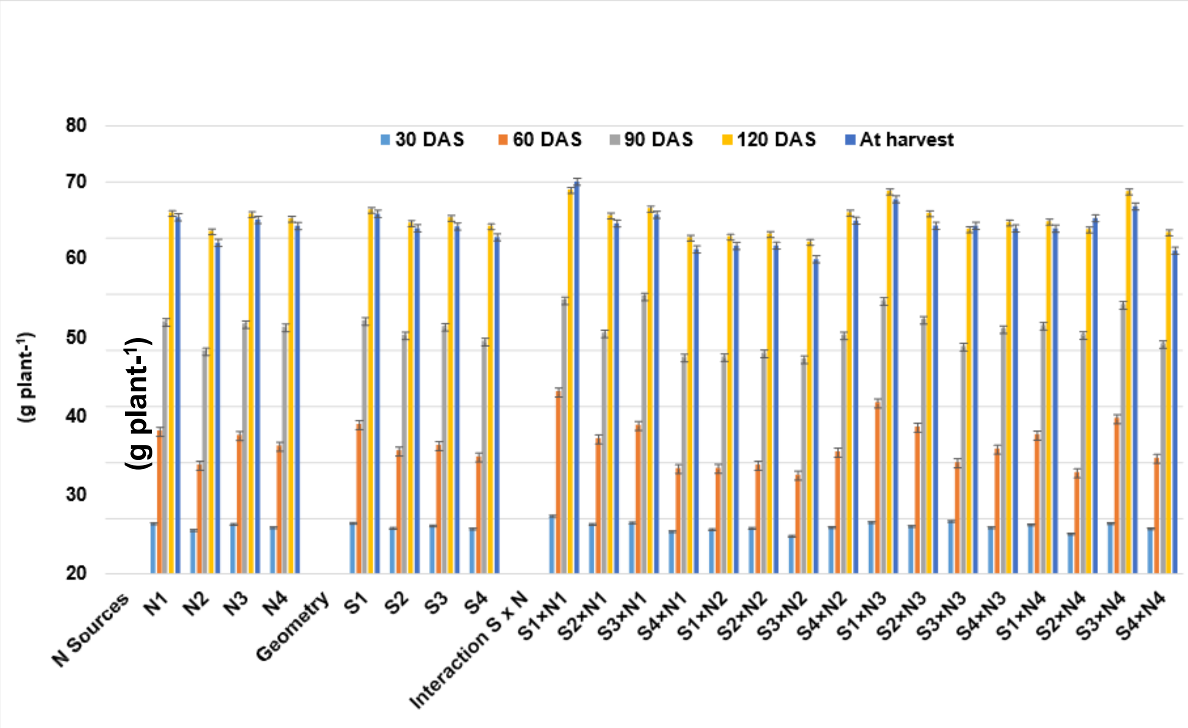


Fig.-2 Effect of nitrogen sources, planting geometries, and their interactions on fresh weight

Dry weight (g plant^{-1}) at 30, 60, 90, 120DAT and at harvest

The dry weight of Kalmegh plants was significantly influenced by nitrogen sources, planting geometries, and their interactions at various growth stages (30, 60, 90, 120 DAT, and at harvest), as presented in Table 3 and depicted in Fig. 3. **At 30 DAT**, the highest dry weight was recorded in S_1-20 x 10 cm (2.76 g), followed by S_3-20 x 20 cm (2.52 g) and S_2-20 x 15 cm (2.25 g). The lowest dry weight was observed in S_4-30 x 10 cm (1.96 g). For nitrogen sources, N_1 (40 kg N through vermicompost + 40 kg N through urea) resulted in the highest dry weight (2.68 g), followed by N_3 (80 kg N through vermicompost) at 2.64 g. The lowest dry weight (2.01 g) was observed with N_2 (60 kg N through vermicompost + 20 kg N through urea). The interaction between planting geometry and nitrogen sources showed significant variation, with the combination of $S_1 \times N_1$ producing the highest dry weight (3.49 g), followed by $S_3 \times N_3$ (3.03 g) and S1 × N3 (3.08 g). The lowest dry weight was recorded in $S_4 \times N_4$ (1.51 g). **At 60 DAT**, the highest dry weight was recorded in S_1-20 x 10 cm (6.92 g), followed by S_3-20 x 20 cm (6.02 g) and S_2-20 x 15 cm (5.70 g), with the lowest in S_4-30 x 10 cm (5.10 g). Among nitrogen sources, N_1 resulted in the highest dry weight (6.81 g), followed by N_3 at 6.35 g. The lowest was observed with N_2 (4.63 g). The interaction between planting geometry and nitrogen sources showed significant variation, with $S_1 \times N_1$ producing the highest dry weight (8.54 g), followed by $S_3 \times N_1$ (7.93 g) and $S_1 \times N_3$ (7.50 g). The lowest dry weight was observed in $S_3 \times N_2$ (3.86 g). **At 90 DAT**, S_1-20 x 10 cm again recorded the highest dry weight (22.98 g), followed by S_3-20 x 20 cm (21.92 g) and S_2-20 x 15 cm (20.62 g), with the lowest in S_4-30 x 10 cm (20.75 g). Nitrogen source N_1 resulted in the highest dry weight (23.06 g), followed by N_3 (21.95 g). The lowest was recorded with N_2 (20.28 g). The interaction between planting geometry and nitrogen sources showed significant variation, with the combination of $S_1 \times N_1$ producing the highest dry weight (28.68 g), followed by $S_3 \times N_1$ (23.67 g) and $S_3 \times N_3$ (22.78 g). The lowest was observed in $S_3 \times N_2$ (19.25 g). **At 120 DAT**, the highest dry weight was recorded in S_1-20 x 10 cm (41.70 g), followed by S_3-20 x 20 cm (40.00 g) and S_2-20 x 15 cm

(39.51 g), with the lowest in S_4-30 x 10 cm (39.01 g). For nitrogen sources, N_1 resulted in the highest dry weight (41.77 g), followed by N_3 (41.28 g). The lowest was observed with N_2 (37.27 g). The interaction effects showed that $S_1 \times N_1$ produced the highest dry weight (46.61 g), followed by $S_3 \times N_1$ (43.66 g) and $S_1 \times N_3$ (43.58 g). The lowest was recorded in $S_3 \times N_2$ (35.34 g). **At harvest**, S_1-20 x 10 cm recorded the highest dry weight (44.22 g), followed by S_3-20 x 20 cm (42.69 g) and S_2-20 x 15 cm (41.69 g), with the lowest in S_4-30 x 10 cm (41.10 g). Among nitrogen sources, N_1 (40 kg N through vermicompost + 40 kg N through urea) recorded the highest dry weight (44.17 g), followed by N_3 (43.87 g). The lowest dry weight (38.82 g) was observed with N_2 (60 kg N through vermicompost + 20 kg N through urea). The combination of $S_3 \times N_1$ produced the highest dry weight (48.07 g), followed by $S_1 \times N_1$ (47.79 g) and $S_3 \times N_4$ (47.42 g). The lowest dry weight was recorded in $S_3 \times N_2$ (36.25 g). The increased dry weight in these treatments likely contributed to higher productivity of Kalmegh, with factors such as fresh herbage yield per plant and per hectare playing a crucial role. These results align with findings from various studies (Husain and Kumar, 2024; Chand et al., 2011; Dakhane and Nandkarm *et al*., 2012; Kanjilal *et al*. 2002; Makwana *et al*., 2010; Ramesh *et al*., 2011; Sanjutha *et al*., 2006; Singh *et al*., 2006), which also reported that organic fertilizers significantly improved yield attributes and overall crop productivity.

Table 3: - Effect of N sources, planting geometries, and their interactions on dry weight (g plant^{-1}) at various growth stages in Kalmegh.

Treatments		30 DAT	60 DAT	90 DAT	120 DAT	At harvest
N Sources						
N_1	**40kg N by vermi+40 kg N by Urea**	2.68	6.81	23.06	41.77	44.17
N_2	**60 kg N by vermi+20 kg N by Urea**	2.01	4.63	20.28	37.27	38.82
N_3	**80 kg N by Vermi**	2.64	6.35	21.95	41.28	43.87
N_4	**RDF**	2.15	5.95	20.97	39.91	42.84
S.Em ±		**0.15**	**0.31**	**0.42**	**0.88**	**0.95**
CD at 5%		**0.44**	**0.89**	**1.21**	**2.54**	**2.74**
Geometry						
S_1	**20 X 10 cm**	2.76	6.92	22.98	41.70	44.22
S_2	**20 X 15 cm**	2.25	5.70	20.62	39.51	41.69
S_3	**20 X 20 cm**	2.52	6.02	21.92	40.00	42.69
S_4	**30 X 10 cm**	1.96	5.10	20.75	39.01	41.10
S.Em ±		**0.15**	**0.31**	**0.42**	**0.88**	**0.95**
CD at 5%		**0.44**	**0.89**	**1.21**	**2.54**	**2.74**
Interaction S (Geometry) x N (Sources)						
$S_1 \times N_1$		3.49	8.54	28.68	46.61	47.79
$S_2 \times N_1$		2.58	6.11	20.55	40.77	42.77
$S_3 \times N_1$		2.70	7.93	23.67	43.66	48.07
$S_4 \times N_1$		1.95	4.63	19.33	36.03	38.03
$S_1 \times N_2$		2.03	4.71	19.78	36.11	38.11
$S_2 \times N_2$		2.10	4.75	20.14	37.19	38.49
$S_3 \times N_2$		1.65	3.86	19.25	35.34	36.25
$S_4 \times N_2$		2.27	5.19	21.97	40.43	42.43
$S_1 \times N_3$		3.08	7.50	22.68	43.58	46.47

S_2×N_3	2.37	7.07	21.05	40.66	46.01
S_3×N_3	3.03	5.13	22.78	37.43	39.00
S_4×N_3	2.09	5.69	21.29	43.43	44.00
S_1×N_4	2.45	6.93	20.77	40.50	44.52
S_2×N_4	1.93	4.87	20.74	39.44	39.48
S_3×N_4	2.72	7.13	21.99	43.55	47.42
S_4×N_4	1.51	4.88	20.39	36.13	39.94
S.Em ±	**0.30**	**0.62**	**0.84**	**1.76**	**1.90**
CD at 5%	**0.88**	**1.78**	**2.41**	**5.08**	**5.47**

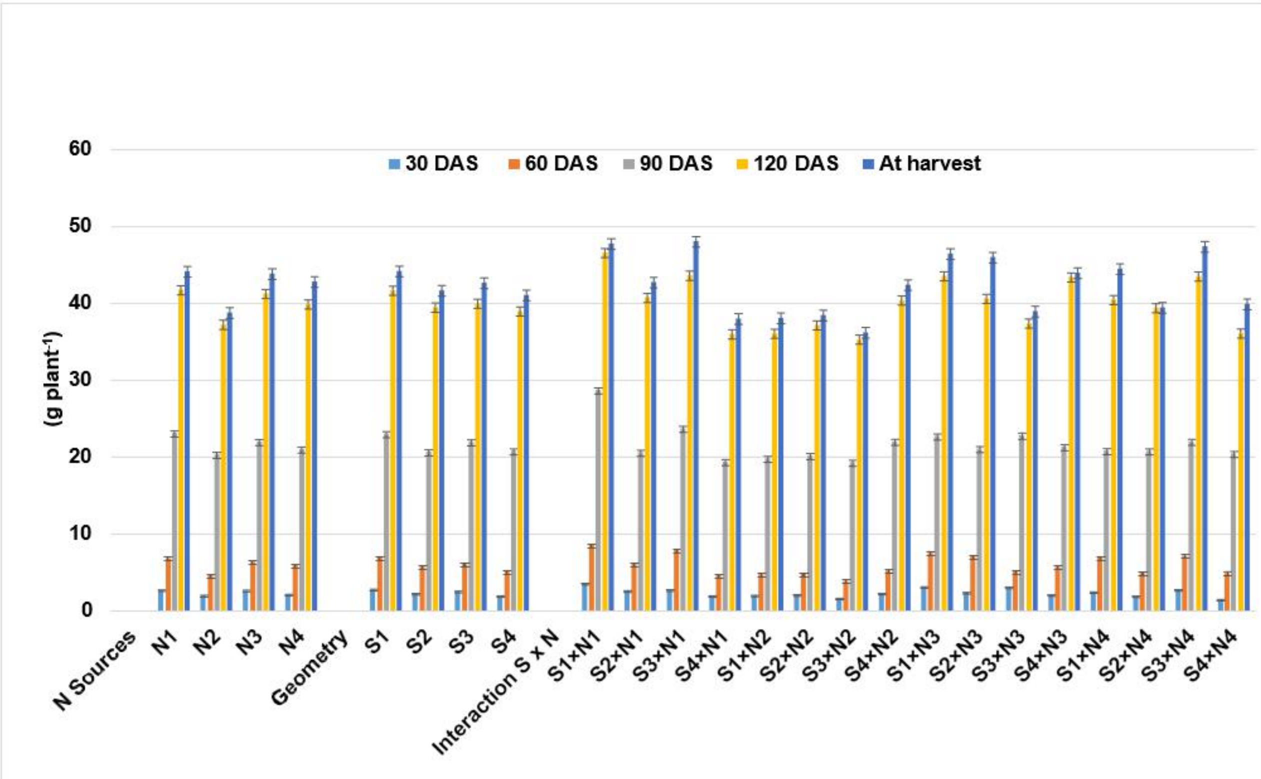


Fig 3:- Effect of nitrogen sources, planting geometries, and their interactions on dry weight (g plant^{-1}) at various growth stages in Kalmegh.

REFERENCES

[1] Chand S, Pandey A, Anwar M and Patra DD. Influence of integrated supply of vermicompost, biofertilizer and inorganic fertilizer on productivity and quality of rose scented geranium (*Pelargonium species*). *Indian J. Natural Products and Resources*. 2011;**2**(3):375-382.

[2] Dakhane VP, Nandkar PB. Influence of nutrients on growth and medicinal content of *Andrographis paniculata* Wall. Ex. Nees. *Bionano Fronter*. 2012; **5**:2-11.

[3] Farooqi A. A.; Sreeramu B. S.. Cultivation of Medicinal and Aromatic Crops; *Universities Press Private Ltd*., 2010; 1–8.

[4] Harisha CB, Sreeramu BS, Umesha K and Vasundra M. Influence of organic manures and biofertilizers on growth and yield of Garden cress (*Lepidium sativum* L.) South Indian Hort. 2010;**45**(1&2):106-108.

[5] Hemalatha P, Suresh J, Balakrishnan S, Natarajan P. Studies on integrated nutrient management in kalmegh (*Androgaphis paniculata* wall Exnees). *South Indian Hort*. 2010;**45**(1&2):148-151.

[6] Husain Mumtaz and Kumar Manoj. Growth and Herbage Yield of Ocimum Sanctum: Vermicompost and nitrogen impact analysis, *International Journal of All Subject Research*. 2024;**3**(1):14-15.

[7] Kanjilal PB, Bordoloi S, Kalita R, Burman P, Singh RS. Cultivation practices of kalmegh (*Andrographis paniculata*)

and spiderling (*Boerhaavia diffusa*) in Assam, India. Recent Progress in medicinal plants. 2002; **5**:175-180.

[8] Kumar Mukesh, Veena Chaudhary. Effect of Integrated Sources of nutrients on growth, flowering, yield and soil quality of Floricultural Crops: A Review. *Int. J. Curr. Microbiol. App. Sci*. 2018;**7**(3):2373- 2404.

[9] Makwana PD, Patel JJ, and Patel HK. Effect of different organic manures and spacing on yield and yield attributes of kalmegh panchang (*Andrographis paniculata* Wall. Ex. Nees) under middle Gujarat conditions. *Int. J. Pl. Sci.* 2010;**5** (1):30-32.

[10] NMPB. Agro-Techniques of Selected Medicinal PlantsVol-2; *NMPB Publication: New Delhi*, 2014,17. https://nmpb.nic.in/sites/default/files/publications/Agro_techniques_of_selected_medicinal_plants_Vol-II.pdf.

[11] Pandey, A.K., 2025. Good Agricultural and Collection Practices of Important Medicinal Plants. In *Textbook of Forest Science* (549-569). Singapore: Springer Nature Singapore.

[12] Panse, V. G. and Sukhatme, P. V. 1985. Statistical Methods for Agricultural Workers. *ICAR, Publ*., New Delhi (India).

[13] Ramesh G, Shivanna MB, Santa RA. Interactive influence of organic manures and inorganic fertilizers on growth and yield of kalmegh (*Andrographis paniculata* Nees). *International Research Journal of Plant Science*. 2011;**2**(1):16-21.

[14] Sadashiv Nadukeri, Kattimani KN, Rokhade AK. Integrated nutrient management in Coleus (*Coleus forskohlii*). National seminar on production, processing and marketing of medicinal, aromatic and dye yielding crops, department of medicinal and aromatic plants, KRCCH, Arabavi, Karnataka, India. 2007;34.

[15] Sanjutha S, Subramanian S, Rajamani K, Vadivel E. Effect of organic manures on growth and yield in Kalmegh (*Andrographis paniculata*) (Burm. F.) Wall. ex. Ness. International conference on “Globalization of traditional, complementary and alternative systems of medicine”, HC&RI, TNAU, Coimbatore; 2006.

[16] Shakywa, R.; Singh, H. and Verma, K. (2022). Response of organic manures and spacing on growth and yield of Kalmegh. *Indian Journal of Agricultural Sciences*, **92**:56-62.

[17] Sharangi, A.B., Rab, S.O., Saeed, M., Alabdallah, N.M. and Siddiqui, S., 2025. Bioformulation-Mediated Response of Kalmegh (*Andrographis paniculata* Wall. ex Nees, Family Acanthaceae) for Growth, Yield, and Quality. *ACS omega*, **10**(7), p.6927.

[18] Singh M, Singh A, Tripathi RS, Verma RK, Gupta MM, Mishra HO, Singh HP, Singh AK. Growth behavior, biomass and diterpenoid lactones production in kalmegh (*Andrographis paniculata* Nees.) strains at different population densities. Agricultural Journal. 2011;**6**(3):115-118.

[19] Trisilawati O.; Hartoyo B.; Bermawie N.; Pribadi E. R. Application of AMF (Arbuscular Mycorrhizal Fungi) and organic fertilizer to increase the growth, biomass and bioactive content of *Centella*. IOP Conf. Series: Earth Envi. Sci. 2019, 292, 012067 10.1088/1755-1315/292/1/012067.

[20] Verma H.; Negi M. S.; Joshi A.; Belal B.; Shukla A.; Mahapatra B.; Jaipaul Growth Attributes of Kalmegh [*Andrographis paniculata* (Burm. F.) Wall Ness] as influenced by integrated nutrient management under tarai conditions of Uttarakhand. *Int. J. Chem. Stud.* 2018, **6** (5), 2947–2949.

[21] Verma R.; Misra V.; Tieari D.; Bisen P. S.. Potential of Selected Indian Herbs for Covid-19 2021. www.researchnet.net/publication/344878741.

[22] Verma, Himanshu, M. S. Negi, B. S. Mahapatra, Anil Shukla, Jai Paul, Manoj Kumar Bhatt, S. P. Singh, and Om Prakash. "Growth, yield, andrographolide content and total antioxidant activity of Kalmegh [Andrographis paniculata (Burm. f.) Wall. ex Nees] under variable nitrogen rates and organic manures application in Indo-Gangetic plains of India." *Journal of Plant Nutrition* 47, **20** (2024): 4048-4060.