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Response of recommended dose of fertilizers with organic manures on growth, yield and economics of kalmegh (*Andrographis paniculata* Nees.): A way to reduced use of chemical Fertilizers

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Abstract
Background: Integrated application of nutrients is an important issue among the formers for obtaining higher growth and yield of kalmegh. Nutrients must be accessible at right time, proportion and quantity.
Aim and Objective: To fulfill these necessities, chemical fertilizers and organic manures are required in integrated manner. Chemical fertilizers have ensured readily availability of particular nutrient for initial but organic sources release slow and long term availability of many nutrients and they improved the efficacy and reduced the quantity of chemical fertilizers.
Materials and Methods: Therefore, fields study was taken up to bridge the gap at department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, RVSKVV, Mandsaur, (M.P.) during the *Kharif* season 2021-22 in RBD Design with three replications. The treatments accompanied with RDF NPK @ 50:30:30 kg ha^{-1}, FYM @ 7.5 & 15 T ha^{-1} and vermicompost @ 0.5 & 1.0 T ha^{-1} along with a control plot without any supplements.
Results: The result indicated that, the significant maximum plant height, number of branches, number of leaves, leaf area, leaf area index, relative growth rate, crop growth rate, biomass production at different growth stages and number of seeds per pod, pod length, pod dry weight, harvest index, dry herbage yield, seed yield, cost of cultivation, gross return, net return and benefit: cost ratio were observed in treatment T_8-100% RDF+100% FYM+100% vermicompost.
Conclusion: The treatment T_8-100% RDF @ 50:30:30 kg ha^{-1}+100% FYM @ 15 t ha^{-1}+100% vermicompost @ 1 t ha^{-1} is found to be the best for achieving the highest growth and yield of kalmegh.

Keywords: *Andrographis paniculata*, dry matter yield, growth, organic manures and RDF

1. Introduction
Kalmegh is a member of family Acanthaceae and a powerful medicinal herb used in Ayurveda, Siddha and Unani (Sharma *et al*., 2013) [1], generally known as "King of Bitter" (Naleena *et al*., 2019) [2]. It is having a preventive result from various diseases, because of its powerful immune strengthening benefits. The whole plant is used to cure snake bite, dried leaf against high blood pressure, gastric and liver tonic. It's have good "blood purifying" activity so, it is recommended for gonorrhea, leprosy, boils, skin eruptions, scabies, and chronic and seasonal fevers (Shwetha *et al*., 2021) [3]. It is take the height of 30-80 cm under suitable environments, leaves are 2.5 cm wide and 7.5 cm long, and flower is zygomorphic, complete and bisexual. The stem is quadrangular with more branches (Srivastava, 2017) [4]. Its fruit is linear, oblong and acute at both the ends and called as capsule with slight, yellowish brown colour seed. Plants are shows non synchronous maturity and diffused seeds frequently through capsule dehiscence (Shakywa *et al*., 2022) [5]. The key active ingredients of kalmegh are di-terepene lactones, andrographolide, andrographiside, neo andrographo-lide and flavones (Sharma *et al*., 2013) [1]. Kalmegh is natural grown in India and Sri Lanka and it is spread all over Thailand, Peninsular Malaysia to Indonesia. In India it is cultivated in the state of Madhya Pradesh, Odisha, Chhattisgarh, Assam, Maharashtra, Uttar Pradesh, Bihar, West Bengal, Tamil Nadu and Kerala. All the fertilizers in the forms of chemical source of nutrients have ensured readily availability of particular nutrient for initial requirement of plants but through organic sources they release slow and long term availability of many nutrients Naleena *et al*. (2019) [2]. For vigorous growth and higher yield, nutrients must be accessible to plants at right time, proportion and quantity.

To fulfill these necessities, both chemical fertilizers and organic manures are required in integrated manner. Improved the efficacy and reduced the quantity of chemical fertilizers when applied with organic manures (Goel *et al*., 2013) [6]. Organic manures are known to eco-friendly, cost-effective and renewable source of plant nutrients which play a vital role in enhancing long term soil fertility and sustainability (Kumar *et al*., 2018) [7]. Therefore, integrated application of nutrients is an important issue among the formers for obtaining higher growth and yield but there is absence of information for integrated nutrient management in kalmegh. Hence, fields study was taken up to bridge the gap in our understanding

2. Materials and Methods

The experiment was carried out with eight treatments in simple Randomized Block Design and replicated three times at department of Plantation, Spices, Medicinal and Aromatic Crops, College of Horticulture, Mandsaur, (M.P.) during the Kharif 2021-22. The treatments accompanied with recommended dose of fertilizes NPK @ 50:30:30 kg ha^{-1}, FYM @ 7.5 & 15 T ha^{-1} and vermicompost @ 0.5 & 1.0 T ha^{-1} along with a control plot without any supplements. Nitrogen (Urea), Phosphorus (Single super phosphate) and Potassium (Murate of potash) were applied as recommended dose of fertilizers. Among these, nitrogen was applied in three equal split doses at before transplanting, 30 & 60 days after transplanting and full dose of phosphorous and potassium at before transplanting. Full dose of farm yard manure and vermicompost mixed well at the time of field preparation as per treatment combination. All the parameters were noted at 30, 60, 90, 120 days after transplanting and at harvest. Site of the experiment is located in the Malwa plateau in the western part of Madhya Pradesh and belongs to sub-tropical and semi-arid climatic conditions. The statistical analysis of variance for the applied design (RBD) was analyzed using Genstat software (2005 Edition). The F-test was measured at the $p<0.05$ level of significance.

3. Results

3.1 Morphological parameters

All the morphological data were enhanced significantly with advancement of growth stages and data are depicted in Table 1 & 2. However, treatment T_8-100% RDF+100% FYM[1]+100% vermicompost had maximum plant height (23.35, 35.83, 42.62, 48.37, 50.49 cm), number of branches (6.50, 16.00, 19.09, 21.00 & 21.33), number of leaves (31.67, 190.47, 219.55, 244.00 & 122.07) and leaf area (10.05, 50.03, 110.23, 137.50 & 137.53 cm^2 $plant^{-1}$) which was at par with T_7-50% RDF+50% FYM+50% vermicompost than significantly higher over the remaining treatments at 30, 60, 90, 120 DAT and at harvest, respectively. The lowest plant height, number of branches, number of leaves and leaf area were found in the T_1 - control.

Table 1: Effect of recommended dose of fertilizers with organic manures on plant height and number of branches of kalmegh

Treatments		Plant height (cm)					Number of branches				
		30 DAT	60 DAT	90 DAT	120 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	At harvest
T_1	Control	14.30	23.80	33.60	37.30	37.60	4.54	10.46	13.86	14.33	14.58
T_2	100% RDF 50:30:30 kg ha^{-1}	16.17	25.75	35.33	39.10	39.78	5.13	12.06	15.93	15.93	16.66
T_3	50% RDF + 50% FYM @ 7.5 t ha^{-1}	18.30	26.91	36.33	40.18	40.95	5.87	13.13	16.20	16.53	18.40
T_4	50% RDF + 100% FYM @ 15 t ha^{-1}	20.62	29.72	39.42	43.11	43.25	6.27	14.53	17.87	19.70	19.93
T_5	50% RDF + 50% vermicompost @ 0.5 t ha^{-1}	20.50	28.62	37.61	41.40	41.66	5.93	14.27	17.20	19.47	19.60
T_6	50% RDF + 100% vermicompost @ 1 t ha^{-1}	21.32	30.76	40.15	44.43	46.07	6.40	15.20	18.00	19.87	20.47
T_7	50% RDF + 50% FYM + 50% vermicompost	22.60	32.02	41.13	46.08	47.54	6.47	15.47	18.13	20.47	21.00
T_8	100% RDF + 100% FYM + 100% vermicompost	23.35	35.83	42.62	48.37	50.49	6.50	16.00	19.09	21.00	21.33
S.Em. ±		0.63	0.28	0.24	0.68	0.45	0.43	1.08	0.37	0.18	0.15
C.D. at 5%		1.92	0.86	0.74	2.07	1.38	1.31	3.27	1.12	0.54	0.44

Table 2: Effect of recommended dose of fertilizers with organic manures on number of leaves and leaf area of kalmegh

Treatments		Number of leaves					Leaf area (cm^2 $plant^{-1}$)				
		30 DAT	60 DAT	90 DAT	120 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	At harvest
T_1	Control	23.47	124.33	174.20	191.67	91.27	6.15	39.87	100.60	125.47	125.49
T_2	100% RDF 50:30:30 kg ha^{-1}	23.93	147.80	181.93	213.00	109.47	6.23	41.23	102.10	127.20	127.23
T_3	50% RDF + 50% FYM @ 7.5 t ha^{-1}	28.40	152.00	183.33	216.67	115.87	6.53	42.60	103.03	128.73	128.77
T_4	50% RDF + 100% FYM @ 15 t ha^{-1}	29.40	160.73	193.80	220.00	119.20	7.26	45.13	105.13	131.27	131.31
T_5	50% RDF + 50% vermicompost @ 0.5 t ha^{-1}	28.27	157.80	185.13	216.93	115.93	6.90	43.30	104.57	129.40	129.42
T_6	50% RDF + 100% vermicompost @1 t ha^{-1}	30.80	163.33	197.27	227.40	120.93	8.41	46.30	106.97	132.27	132.31
T_7	50% RDF + 50% FYM + 50% vermicompost	30.87	179.27	213.27	235.00	121.73	9.40	48.53	108.57	135.27	135.30
T_8	100% RDF + 100% FYM + 100% vermicompost	31.67	190.47	219.55	244.00	122.07	10.05	50.03	110.23	137.50	137.53
S.Em. ±		1.09	17.21	1.96	3.93	5.07	0.13	0.24	0.16	0.23	0.23
C.D. at 5%		3.30	52.19	5.94	11.92	15.37	0.39	0.73	0.47	0.70	0.70

3.2 Growth parameters

The significant differences were exhibited among the growth parameters and data are graphically illustrated in Figure 1. On perusal of data exhibited that, treatment T_8-100% RDF+100% FYM+100% vermicompost was accumulated higher leaf area index (0.023, 0.106, 0.095 & 0.106), leaf area duration (901.30, 2404.00, 3716.00 & 4125.40 cm^2 $days^{-1}$), relative growth rate (0.049, 0.073, 0.073 & 0.037 g g^{-1} $days^{-1}$) and crop growth rate (0.112, 0.212, 0.226 & 0.077 g cm^{-2} $days^{-1}$) which was at par with T_7-50% RDF+50% FYM+ 50% vermicompost but significantly differed with other treatments at 30-60, 60-90, 90-120 DAT and 120- at harvest, respectively. The minimum leaf area index, leaf area duration, relative growth rate and crop growth rate were observed in the T_1 - control.

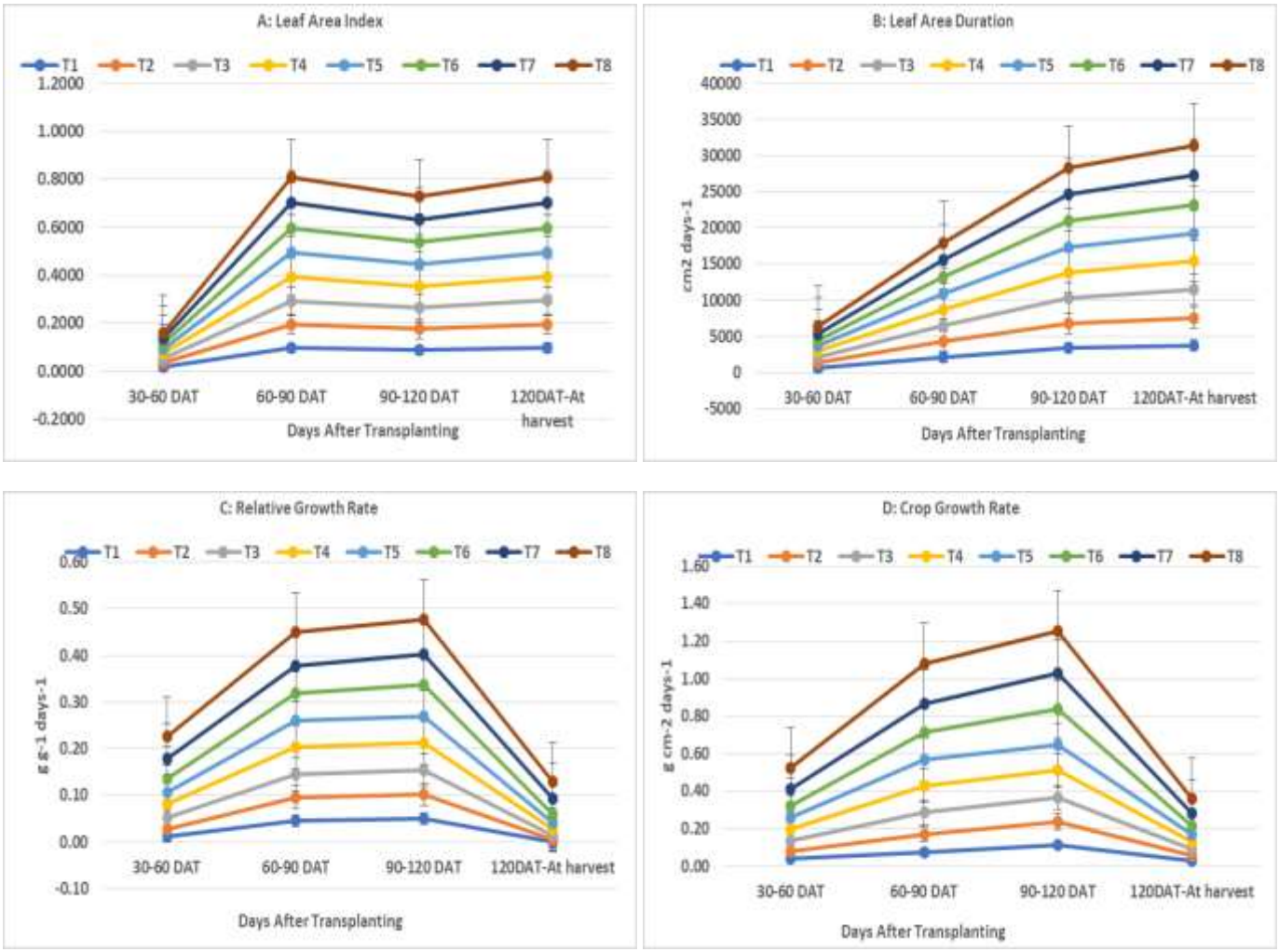

Fig 1: Effect of recommended dose of fertilizers with organic manures on growth parameters of kalmegh

3.3 Biomass production

During investigation significant differences were revealed among the biomass production and data are show diagrammatically in Figure 2. The statistical analysis of data manifested that, treatment T_8- 100% RDF+100% FYM+ 100% vermicompost was assessed highest fresh weight (10.68, 23.31, 47.10, 73.50 & 73.53 g $plant^{-1}$) and dry weight (3.98, 8.37, 17.36, 26.17 & 29.19 g $plant^{-1}$) which was at par with T_7-50% RDF + 50% FYM+ 50% vermicompost but significantly differed over the remaining treatments at 30, 60, 90, 120 DAT and at harvest, respectively. The lowest value of fresh weight and wry weight were shown in the T_1 - control.

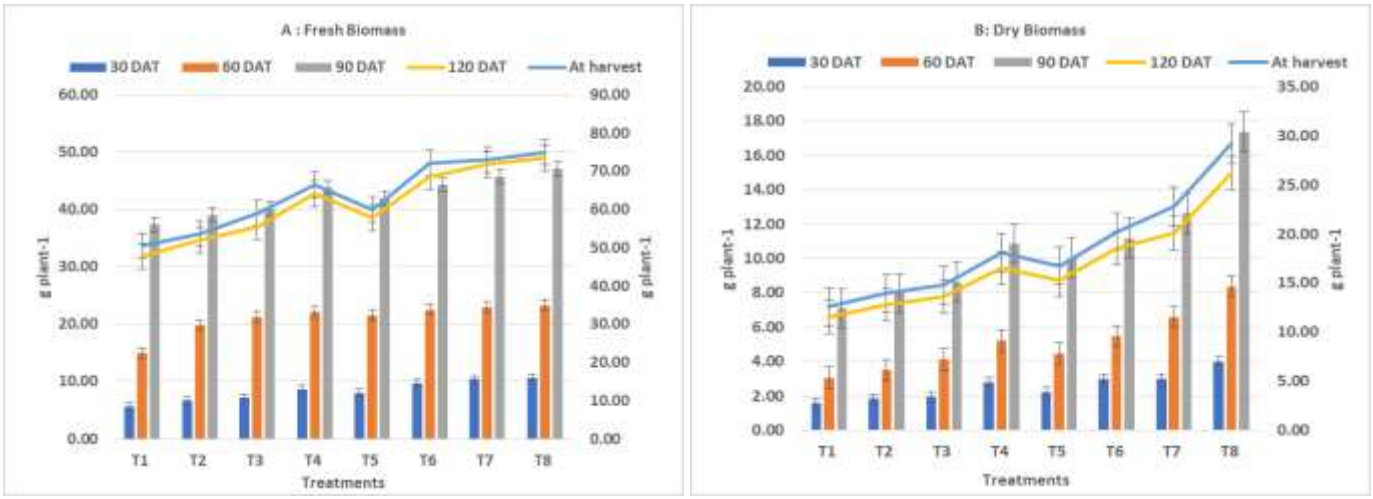

Fig 2: Effect of recommended dose of fertilizers with organic manures on dry matter production of kalmegh

3.4 Yield and their components

The significant differences were indicated among the yield and yield attributing traits and data is represented in Table 3. On perusal of data exhibited that, treatment T_8-100% RDF+100% FYM+100% vermicompost had higher number of pods (176.51), number of seeds pod^{-1} (11.67), pod length (1.72 cm), pod dry weight (11.47 g), harvest index (6.67%), dry herbage yield (2660.95 kg ha^{-1}) and seed yield (171.59 kg ha^{-1}) which was at par with T_7 -50% RDF+ 50% FYM+ 50% vermicompost but significantly superior over the remaining treatments. The lowest number of pods, number of seeds pod^{-1}, pod length, pod dry weight, harvest index, dry herbage yield and seed yield were observed in the T_1 - control.

Table 3: Effect of recommended dose of fertilizers with organic manures on yield and their components of kalmegh

Treatments		Number of pods (Plant^{-1})	Number of seeds (Pod^{-1})	Pod length (cm)	Pod dry weight (g plant^{-1})	Harvest Index (%)	Seed yield (kg ha^{-1})	Dry herbage yield (kg ha^{-1})
T_1	Control	127.40	7.50	1.48	8.28	4.42	111.05	1885.97
T_2	100% RDF 50:30:30 kg ha^{-1}	144.80	7.67	1.50	9.41	5.12	111.11	2058.63
T_3	50% RDF + 50% FYM @ 7.5 t ha^{-1}	146.73	8.33	1.52	9.53	5.50	122.96	2112.19
T_4	50% RDF + 100% FYM @ 15 t ha^{-1}	173.53	8.67	1.60	11.28	5.99	147.40	2311.59
T_5	50% RDF + 50% vermicompost @ 0.5 t ha^{-1}	147.93	8.33	1.53	9.62	5.68	131.85	2191.67
T_6	50% RDF + 100% vermicompost @ 1t ha^{-1}	174.53	9.83	1.63	11.35	6.09	155.56	2397.73
T_7	50% RDF + 50% FYM + 50% vermicompost	175.52	10.67	1.68	11.40	6.65	165.45	2560.73
T_8	100% RDF +100% FYM+100% vermicompost	176.51	11.67	1.72	11.47	6.67	171.59	2660.95
S.Em. ±		3.79	0.25	0.04	0.05	0.07	1.70	2.87
C.D. at 5%		11.50	0.75	0.12	0.16	0.22	5.18	8.70

3.5 Economics of the treatments

The result revealed from Table 4 that, treatment T_8 -100% RDF+100% FYM+100% vermicompost had maximum cost of cultivation (₹ 62101.41), gross return (₹ 199776.75), net return (₹ 137675.34) and benefit: cost ratio (2.20) while minimum cost of cultivation (₹ 38426.45), gross return (₹ 93868.25), net return (₹ 55411.80) and benefit: cost ratio (1.40) T_1 - control.

Table 4: Effect of recommended dose of fertilizers with organic manures on economics of kalmegh

Treatments		Economics			
		Cost of cultivation (₹)	Gross return (₹)	Net return (₹)	B:C Ratio
T_1	Control	38426.45	93868.25	55411.80	1.40
T_2	100% RDF 50:30:30 kg ha^{-1}	45601.41	123687.25	78085.84	1.70
T_3	50% RDF + 50% FYM @ 7.5t ha^{-1}	55216.38	142728.75	77512.37	1.50
T_4	50% RDF + 100% FYM @ 15t ha^{-1}	56466.38	153599.75	97133.37	1.70
T_5	50% RDF + 50% vermicompost @ 0.5t ha^{-1}	45966.38	140494.25	94527.87	2.10
T_6	50% RDF + 100% vermicompost @ 1t ha^{-1}	52966.38	161057.25	108090.87	2.00
T_7	50% RDF + 50% FYM + 50% vermicompost	57216.38	182442.25	125225.87	2.10
T_8	100% RDF+100% FYM+100% vermicompost	62101.41	199776.75	137675.34	2.20

4. Discussion

4.1 Morphological parameters

The result indicated that, treatment T_8-100% RDF+100% FYM+100% vermicompost had significantly enhanced all the morphological parameters during course of the investigation. However, the percentage of growth was increased with the advancement of growth stages which were 22.73, 35.16, 41.83, 47.59 & 49.47% in plant height and 49.75, 5.80, 15.35,

18.36, 20.32 & 20.65% in number of branches, 25.89, 34.72, 20.66, 21.45 & 25.23% in number of leaves and 38.81, 20.31, 8.74, 8.75 & 8.75 % in leaf area as compared to control plants at 30, 60, 90, 120 DAT and at harvest, respectively. The percentage of growth was increased for plant height and number of branches at different growth stages but number of leaves and leaf area growth percentage was increased in initial growth stage and further declined till harvest due to maturation and leaf senescence. This might be due to balanced application of organic manures in mixture with inorganic fertilizers could be ascribed to enhancement in soil health and raised availability of both macro and micro nutrients to the crop or it might be because of fact that nutrient released from both organic and inorganic fertilizers would have resulted in the extended nutrient availability which in turn increased the translocation of photosynthates and optimum vegetative growth, according to Naleena *et al*. (2019) [2]; Cheena *et al*. (2020) [8].

4.2 Growth parameters

It was manifested that, all the growth parameters were significantly affected with the application of recommended dose of fertilizer, farm yard manure and vermicompost at different plant growth phase. The present study exhibited that, the highest percentage of growth of leaf area index (21.74, 9.43, 8.42 & 8.49%), leaf area duration (23.42, 12.35, 8.75 & 8.75 %), relative growth rate (77.55, 36.99, 31.51 & 97.30%) and crop growth rate (66.96, 65.57, 49.56 & 64.94%) was found in treatment T8-100% RDF+100% FYM+100% vermicompost over control at 30-60DAT, 60-90DAT, 90-120 DAT and 120 DAT-at harvest, respectively. The growth percentage of leaf area index and leaf area duration were declined after 60 days after transplanting, may be due to falling down of leaves with advancement of growth stage and senescence. This might be because of decreased number of leaves per plant, according to Nishchitha *et al*. (2018) [8]. The relative and crop growth rate indicated higher magnitudes at very early stage of growth i.e. 30-60 days after transplanting followed by a reduction and again higher percentage of growth till harvest. The higher magnitudes in the early growth phase and reduction in later growth phase was attributed to the higher leaf area in the early growth period and reduction in the later phase of growth (Patidar *et al*., 2019) [10]. From the above results it may be stated that the use of chemical fertilizers along with organic manures in integrated manner is beneficial in enhancing the growth of *Andrographis paniculata*, reported by Shwetha *et al*. (2021) [3].

4.3 Biomass production

The biomass production of kalmegh was significantly influenced with application of inorganic and organic fertilizers. However, the higher percentage of growth of fresh weight (47.19, 35.86, 20.64, 35.01 & 32.70 %) and dry weight (59.55, 63.32, 59.10, 55.87 & 56.83 %) were recorded in treatment T_8-100% RDF+ 100% FYM+100% vermicompost as compared to control at 30, 60, 90, 120 DAT and at harvest, respectively. Increase in yield due to the supply of essential nutrients in available forms that too in sufficient quantities can lead to increased plant growth. Thus, the highest herbage yield noted in the present experiment with the applying of biofertilizers and vermicompost can be attributed to mineralization and mobilization of nutrients which increase plant nutrient absorption. Also, as a result of the combined usage of organic and inorganic fertilizers results in the stable release of both micro and macro nutrients to the plant. This assists in the development of more plant tissues, resulting in abundant vegetative growth, reported by Shwetha *et al*. (2021) [3].

4.4 Yield and their components

The significant variations were observed in yield and yield attributing parameters and the data are presented in Table 4.11. However, the higher increased percentage over control was recorded in number of pods (27.82%), number of seed per pod (35.73%), pod length (13.95%), pod dry weight (27.81%), harvest index (33.73%), seed yield (35.28%) and dry herbage yield (29.12%) were found in treatment T_8-100% RDF+100% FYM+100% vermicompost. The applying of both inorganic and organic nutrients might have resulted in quick translocation, synthesis and accumulation of photosynthates from source to sink which might have ultimately contributed to enhanced number of pods, suggested by Shwetha *et al*., 2021. The superior yield achieved in kalmegh due to integration of inorganic fertilizers and organic manures could be because of the higher yield attributing characters by higher supply of nutrients, suitable physical and biological environment with raised organic carbon in the soil leading to greater root activity and nutrient uptake. Application of organic manures along with chemical fertilizers are enhanced of soil physical environment might be helped in better development of root growth, reported by Bhargavi *et al*., 2017 [11]. Similar results was observed by Kumar *et al*. (2018) [7] and Nishchitha *et al*. (2018) [9].

4.5 Economics of the treatments

The analysis of variance pertaining from Table 4.14 that, treatment T_8-100% RDF+ 100% FYM+100% vermicompost had maximum cost of cultivation (62101.41Rs. ha^{-1}), gross return (199776.75 Rs. ha^{-1}), net return (137675.34 Rs. ha^{-1}) and benefit: cost ratio (2.2) as compared to T_1 - control. The intensification in the net return may be attributed to supply of optimal level of nutrients by using organic manures and chemical fertilizer's to meet the crop mandate at proper time which in turn lead to higher yield Dhanush *et al.* (2018) [12].

Plate 1: A panoramic view of the experimental field of kalmegh

5. Conclusion

On the basis of one year research, it could be concluded that, the treatment T_8-100% RDF@50:30:30kg ha^{-1}+100% FYM@15t ha^{-1}+100% vermicompost@1t ha^{-1} is found to be the best for achieving the highest growth and yield of kalmegh.

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7. Declaration of Conflicting Interests
The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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