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Flower Yield Potential of Pyrethrum (*Chrysanthemum cinerariaefolium* L.) under Various NPK Levels in the Lower Hills of Uttarakhand, India

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ABSTRACT

Purpose: *A favorable environment is available for the cultivation of Pyrethrum in the hilly regions of India, as well as in some mountainous areas of India. In view of the demand for Pyrethrin, it is very necessary to promote the huge cultivation of Pyrethrum. There is no misconception that research work has not been done to promote Pyrethrum, but the data related to the assessment of the right amount of nutrients required for the crop is not available in research related to agrotechnology. If the crop is to be taken as a ratoon crop, then it is very important to estimate the amount of nutrients for single recommendation of crop cultivation*

Research Method: *A research experiment was conducted in the year 2021 at the CSIR-Central Institute of Medicinal and Aromatic Plant Research, Centre Purara, Bageshwar (Uttarakhand) to study the flower yield potential of Pyrethrum under various NPK levels in the lower hills of Uttarakhand. The experiment was carried out in Complete Randomized Block Design. The six different levels of NPK (kg ha^{-1}) were taken as treatments, i.e., control, 60:60:20, 80:70:30, 100:80:40, 120:90:50, and 150:100:60. Various plant growth and yield parameters considered in the study include plant height (cm), plant diameter (cm), number of flower heads, fresh flower weight plant^{-1} (g), dry flower weight plant^{-1}(g), fresh flower yield (kg ha^{-1}), dry flower yield (kg ha^{-1}), Pyrethrin concentration (%) and yield (kg ha^{-1}).*

Findings: *Based on the research findings, it seems that the NPK level of 120:90:50 is the best combination to obtain the highest dry flower yield (310.49 kg ha^{-1}) in the lower hills of Uttarakhand. However, the fresh flower weight obtained was the highest under the NPK level of 100:80:40 i.e., 840.47 kg ha^{-1}, but it's dry flower yield estimated was 301.93 kg ha^{-1} which was the second highest yield after 310.49 kg ha^{-1}. This could be due to the difference in moisture levels in fresh flowers at the time of harvesting.*

Research Limitations: *Considering the climate of the hilly regions of Uttarakhand, not much work has been done to assess and standardize the proper amount of nutrients required for Pyrethrum crop cultivation, which needs to be done.*

Originality/ Value: *In the hilly areas of Uttarakhand, farmers are interested in the cultivation of Pyrethrum, but if farmers will adopt this crop cultivation as a ratoon crop, then in such a situation it is absolutely necessary to assess the proper amount of nutrients. This research will prove helpful in promoting the cultivation of Pyrethrum in the hilly areas of Uttarakhand.*

Keywords: *Flower, insecticide, nutrient, pyrethrin, pyrethrum*

INTRODUCTION

Pyrethrum (*Chrysanthemum cinerariaefolium* L.) is a member of the Asteraceae family. It is a perennial temperate plant mostly used for its flowers, which contain the natural insecticide known as Pyrethrins (Korir *et al.,* 2021).

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Pyrethrum is a native of the Balkan Peninsula in eastern Europe. The plant has a daisy like appearance, bearing white ray flower petals, surrounding the yellow centre head. The leaves are greenish-gray in color and are deeply divided (Neil *et al*., 2021). The Pyrethrum plant is slender, tufted, and herbaceous in nature, growing up to a height of one metre (Brown and Menary, 1994). Around 94% of the Pyrethrins are produced in the oil glands present in the mature Pyrethrum flower, with a slight percentage of oil glands and secretory ducts also present in other parts of the plant like leaves, stems, and roots (Zito, 1994).

Pyrethrins are the secondary metabolites that are extracted from the achenes within the flower heads (Grdiša *et al*., 2022), and have economic importance for making natural pesticides. Pyrethrins are neurotoxic and effective against a wide range of insect species. Being natural and organic in nature, these are widely used in private homes, kitchen gardens, and organic agriculture because of their environmentally friendly properties (Yang *et al.,* 2014). It can also be used in powder form which is obtained by crushing the dried flowers.

Pyrethrins can be separated into two groups of three ester compounds, i.e., Pyrethrins I and Pyrethrins II. Pyrethrin I contains Chrysanthemic acid products, like, Cinerin I, and Jasmolin I. The Pyrethrin II fraction is a derivative of Pyrethric acid, and it's made by Pyrethrin II, Cinerin II, and Jasmolin II.

The compounds present in both Pyrethrin I and II contain insecticidal properties (Martin, 2008). These compounds are also referred to as "Knockdown," killing a wide range of insects and having less toxicity towards mammals. Pyrethrins also have the advantage over other synthetic and chemical insecticides as they are rapidly broken down and metabolized upon exposure to light and air (Carol *et al*., 2018). Thus, natural Pyrethrins are generally considered environmentally friendly. Pyrethrins have been listed for use in pesticides since the 1950's, and since then they have been used as a model for the preparation of synthetic chemicals called "Pyrethroids," which are similar to Pyrethrins (Dilnee *et al.,* 2017). Pyrethrins are found as a component in around 2,000 registered pesticides, and pyrethrins are mixed with chemicals known as "Synergists" to increase their efficacy (Johnson *et al.,* 2010).

The Pyrethrin toxins, when they come into contact with the insect body, penetrate the insect cuticle and reach the nervous system. These toxins bind to the sodium channels, which are responsible for nerve signal transmission by permitting the flux of sodium ions along the length of nerve cells (Venn *et. al.,* 2021). The normal function of the sodium channels is obstructed by the binding of toxins, resulting in hyperexcitation of the nerve cell. This leads to the loss of function of the nerve cells and the closure of the insect nervous system, finally resulting in insect death (Thorpe, 2016).

Pyrethrum can also be used in organic agriculture or integrated with conventional crop cultivation because of its natural origin and high biocide effects. The Pyrethrum flowers can be used in any form, i.e., either by applying them in the form of a fine, dry powder of flowers or by spraying the flower extract (Martin *et al*., 2008). It can also be used in the form of incense sticks to provide protection against mosquitoes, which cause malaria, and other fleas, moths, and ants. Pyrethrins are used as home and garden insecticides. Commercial uses of Pyrethrins include home indoor sprays, pet shampoos, aerosol bombs to kill flying insects, and jumping insects. Although they are considered natural and low-toxic to mammals, insecticide poisoning events have been found to be common in them, like headaches, dizziness, and difficulty in breathing (Koul *et al.,* 2019). In severe cases, it can also cause life-threatening allergies and result in severe asthma. Pyrethrin, when it comes into contact with human skin, causes irritation, which gets worsened by sun exposure (Martin and Hester, 2006; Pethybridge *et al.,* 2008). However, absorption of Pyrethrin through the human stomach and intestine is lowa, but it gets quickly absorbed through the respiratory system. Inhaling high amounts of Pyrethrum compounds results in sneezing, nasal stuffiness, headaches, difficulty in breathing, nausea, lack of coordination, facial swelling, and burning and itching sensations (Chrustek *et al.*, 2018; Neil *et al.*, 2021).

Growing pyrethrum in its favorable environment is vitally important to fulfil the present demand for pyrethrin, as it will be a source of income for farmers and aid in preventing the import of pyrethrin. Flowers can be collected for three to four years because pyrethrum is a perennial crop. Now, if we're talking about the proper amount of nutrients on the crop, we have only one year's worth of farming research data and reports available. There is no information available on the nutritional dose for Pyrethrum if it is grown as a ratoon crop. As a result, standardizing the nutrients is important when growing pyrethrum as a ratoon crop. This research experiment was conducted to scrutinize the effect of different levels of NPK on the crop growth and flower yield of a one-year-old standing Pyrethrum crop in the lower hills of Uttarakhand so that the best combination of NPK can be suggested to the local farmers to increase farm income and enhance local industrial growth.

MATERIALS AND METHODS

The research was conducted in the year 2021 at the CSIR CIMAP Research Centre Purara, Bageshwar (Uttarakhand), India, which is set at an altitude of 1500-1560 m MSL. The location lies between the coordinates 29.92°N and 79.62°E. The climate of the research station is tropical to subtropical type with temperatures during the summer ranging from 20° to 30° C, and during the winter, the temperature drops to a minimum of 0°C. The maximum temperature during the winter season rises up to 22°C. The monsoon at the location usually breaks in the month of June and subsides by mid-September. The average rainfall for the year at the experimental site is 48.1" (1221.7mm). The study was conducted between February and June.

To assess the chemical parameters of the soil, a diagonal soil sampling technique was used to collect soil samples from each plot at five points at a depth of 10 cm. The soil pH was 7.23. The electrical conductivity recorded in the soil was 82.18 (μscm^{-1}). The organic carbon content in the soil was 1.17 %. Nitrogen, phosphorus, and potassium in the soil were found to be 285.37 kg ha^{-1}, 25.05 kg $ha^{-1,}$ and 162.4 kg ha^{-1} respectively.

The experiment was laid out in a complete randomized block design with three replications, and various combinations of NPK levels were tested. Nitrogen was split into three doses, with 50% applied initially and 25% in subsequent applications. Phosphorus was divided into two equal parts, while potassium was applied as a single full dose. The first dose, consisting of 50% nitrogen, 50% phosphorus, and the complete dose of potassium, was administered on 28th February. The second dose of 25% nitrogen and 50% phosphorus was applied on 28th March, and the remaining 25% nitrogen was applied on 15th April. Urea, muriate of potash (MOP), and Single Super Phosphate (SSP) were used as fertilizers to supply the required nutrients. The study was conducted on a well-trained and pruned one-year-old standing Pyrethrum crop with a plant-to-plant and line-to-line distance of 50 cm. Intercultural activities such as hoeing, weeding, and irrigation were performed regularly to ensure optimal crop growth and development.

The plant growth parameters studied were plant height (cm), plant diameter (cm), number of flowers, fresh and dry weight of flowers $plant^{-1}$ and fresh and dry flower yield ha^{-1}. Five random plants were selected in each plot, and the observations were taken, then averaged and noted. The plant height was taken with the help of a metre scale from the base to the tip of the plant. The plant diameter was read by placing the meter scale through the centre of the plant. Multiple harvests of fresh flowers at the peak of their bloom were conducted in each plot, and their weights were recorded during the months of April and June. Then the flowers were sun dried until the constant dry weight of flowers was obtained. The flowers were sun-dried for 48 hours, then oven-dried for

2-3 hours at 80°C, then oven-dried at 50°C to a consistent weight, and these dry weights were recorded. A Spectrophotometer method has been used to measure the concentration of Pyrethrins in flowers. (Crowley, 1962). The economics of the crop were calculated under different treatments. The cost of cultivation, gross return, net profit, and B:C ratio were estimated. Net return, B:C ratio, and nutrient uptake were calculated by using the following formula:

(I) NR = Gross Return = Cost of Cultivation

(II) B:C ratio = Gross Return/Cost of Cultivation

(III) Nutrient uptake (Kg ha^{-1}) = Nutrient content (%) X Dry flower (Kg ha^{-1}) /100

The statistical software OPSTAT (http://14.139.232.166/opstat/index.asp), developed by CCS, Haryana Agricultural University, Hisar (Haryana), India, was used for the statistical analysis of data.

RESULTS AND DISCUSSION

Data on phenological plant values at the bud initiation stage and flower yield $plant^{-1}$ were presented in Table 1 & depicted in Figure 01-02. The maximum plant height was observed under the highest NPK level (150:100:60) i.e., 69.37 cm, followed by the treatment NPK 100:80:40 and 120:90:50, the average plant height was observed i.e., 65.25 cm and 66.87 cm, respectively, while under the control treatment the lowest plant height (46.07 cm.) was noticed whereas the similar plant heights were obtained under the treatment with NPK 60:60:20, and 80:70:30 i.e., 61.35 cm and 61.33 cm, respectively. The effect of different levels of NPK doses on plant height was found to be significant. The maximum plant diameter was observed under treatment with the highest NPK ratio (150:100:60), i.e., 22.49 cm. The control plot had an average plant diameter of 18 cm, which was the minimum among all treatments. Plots with NPK ratios of 60:60:20, 80:70:30, 100:80:40, and 120:90:50 had an average plant diameter of 18.4, 20.35, 19.13, and 21.1 cm, respectively. It was noticed that with increasing fertility levels in the soil, the plant height and diameter also increased. The effect of NPK doses on plant diameter was found to be significant, with SEM (±) of 0.61. The average number of flower heads $plant^{-1}$ was observed at its maximum under the treatment with NPK 150:100:60, i.e., 86.8. Whereas, under a control environment, the average number of flowers $plant^{-1}$ was 33.63. The flowers under control environment were small in size and less in numbers. The maximum number of stems were noticed under NPK 150:100:60, i.e., 80.55. Whereas it was the minimum under the control treatment (15.12). The number of stems increased with an increase in the fertility of the soil. The highest fresh weight of flowers $plant^{-1}$ was observed under the NPK level 120:90:50, i.e., 24.13 g $plant^{-1}$. Upon further increase in NPK level, there was a reduction in the value of the fresh weight of the flowers $plant^{-1}$. Under treatment with NPK 150:100:60, the flowers fresh weight $plant^{-1}$was 20.82 g $plant^{-1}$. The minimum fresh weight was obtained under a controlled environment, i.e., 8.99 g. Treatment with NPK 60:60:20, 80:70:30, and 100:80:40 resulted in 13.17 g, 17.56 g and 22.53 g of fresh flower weight $plant^{-1}$ respectively.

Data on fresh/ dry flower yield ha^{-1}, harvesting index (%), Pyrethrin concentration (%), Pyrethrins yield (Kg ha^{-1}) and days to first picking of Pyrethrum flowers under different doses of NPK are presented in Tables 02 & 05. The estimated production of fresh Pyrethrum flowers ha^{1} was highest under the NPK level 120:90:50 (965.2 kg ha^{-1}) whereas it was lowest in the control environment (359.47 kg ha^{-1}). The maximum flower dry weight $plant^{-1}$ was observed at NPK level 120:90:50, i.e., 8.35 g $plant^{-1}$ followed by NPK level 100:80:40, i.e., 7.35 g $plant^{-1}$. The dry flower weight $plant^{-1}$ in plots treated with NPK levels of 60:60:20 and 80:70:30 was 4.84 and 6.1 g $plant^{-1}$ respectively. The dry weight of flowers ha^{-1} was highest estimated at NPK level 120:90:50, i.e., 334 kg ha^{-1} whereas it was lowest in the control environment (114 kg ha^{-1}). The various levels of NPK had a significant effect on the fresh and dry flower yield. The harvesting index was calculated with different treatments of the various NPK levels under experiment. The highest harvesting index was calculated under the plots with NPK levels of 120:90:50 i.e., 27%. It was noticed lowest under the control plots (21%). Treatments with various NPK ratios, i.e., 60:60:20, 80:70:30, 100:80:40, and 150:100:60, had harvesting indexes of 23%, 24%, 25%, and 26%, respectively. The pyrethrin content ranges from 1.32 to 1.35. The plots treated with NPK 120:90:50 and 150:100:60 had the same pyrethrin content, i.e., 1.35%. The plot treated with NPK 100:80:40 had 1.34% pyrethrin. Treatments with NPK 60:60:20 and 80:70:30 had 1.33% of pyrethrin, whereas it was less than 1.32% in the control environment. The highest Pyrethrin yield was estimated under NPK 120:90:50, i.e., 4.51 kg ha^{-1}. Under control, 60:60:20, 80:70:30, 100:80:40, and 150:100:60, the pyrethrin yield was 1.5, 2.57, 3.24, 3.94, and 3.93 kg ha^{-1} respectively. The average number of days to the first picking of flowers (from the first dose of fertilizer application) was noticed least under NPK levels 120:90:50 and 150:100:60, i.e., 30.55 and 30.12 days, respectively. It took a long time under the control plot for the first picking of flowers (50.21 days). It was also observed that different NPK levels had a significant effect on the number of days to first picking, with SEM **(±)** of 0.6.

Table 01: Phenological plant values at bud initiation stage and flower yield plant^{-1} of Pyrethrum at harvest stage

Treatment	Plant height (cm)	Plant diameter (cm)	Number of flower plan^{t-}1	Number of stem plan^{t-}1	Fresh weight of flowers plant^{-1} (g)	Dry weight of flowers plant^{-1} (g)
Control	46.07	18.00	33.63	15.10	8.99	2.85
NPK (60:60:20)	61.35	18.40	75.72	21.33	13.17	4.84
NPK (80:70:30)	61.33	20.35	76.57	35.11	17.56	6.10
NPK (100:80:40)	65.25	19.13	79.70	54.67	22.53	7.35
NPK (120:90:50)	66.87	21.10	84.37	71.82	24.13	8.35
NPK (150:100:60)	69.37	22.49	86.80	80.79	20.82	7.28
Mean	61.70	19.97	72.73	46.47	17.87	6.123
SEM (±)	1.29	0.61	0.77	0.62	0.61	0.18
CD at 0.05 level	4.11	1.95	2.47	1.99	1.93	0.56

Table 02: Flower yield ha^{-1}, harvesting index (%), pyrethrins concentration (%), Pyrethrins yield (Kg ha^{-1}) and days to first picking of Pyrethrum under different doses of NPK.

Treatment	Fresh flower yield ha^{-1} (kg)	Dry flower yield ha^{-1} (kg)	Harvesting index	Pyrethrins		Days to first picking
				Concentration (%)	Yield (Kg ha^{-1})	
Control	359.47	114.00	21	1.32	1.50	50.21
NPK (60:60:20)	526.80	193.60	23	1.33	2.57	42.75
NPK (80:70:30)	702.43	243.87	24	1.33	3.24	39.44
NPK (100:80:40)	901.33	294.13	25	1.34	3.94	32.65
NPK (120:90:50)	965.20	334.00	27	1.35	4.51	30.55
NPK (150:100:60)	832.67	291.20	26	1.35	3.93	30.12
Mean	714.65	245.13	24.33	1.33	3.27	37.62
SEM (±)	24.19	6.99	0.59	0.01	0.09	0.60
CD at 0.05 level	77.21	22.34	1.88	0.02	0.30	1.88

Table 03 and depicted in Figure 03. shows data on the economics of various treatments in the second year of Pyrethrum transplanting. The economic analysis of the crop revealed that the highest net returns were obtained under NPK level 120:90:50, i.e., Rs. 398000, along with the highest B:C ratio of 4.86. Although B:C was found to be greater than 1 under all treatments. The lowest B:C ratio was noticed under a control environment with net returns of Rs.126000, followed by 60:60:20, 80:70:30, 100:80:40, and 150:100:60, calculated at 4.68, 4.81, 4.85 and 3.8, respectively. Different fertility levels had a significant effect on the B:C ratio, with SEM(±) of 0.14.

Data on nutrient uptakes as influenced by different doses of NPK levels are presented in Table 04. The data showed that with increased nutrient delivery in the soil, the nutrient uptake (Kg ha^{-1}) also increased. NPK (170:130:100) had the highest nitrogen uptake (164.27 Kg ha^{-1}), while NPK levels (150:100:80) had the lowest (142.83 Kg ha^{-1}). It was the lowest in control (8.57 Kg ha^{-1}). The NPK (170:130:100) had the highest phosphorus uptake (98.25 Kg ha^{-1}) and was followed by the NPK (150:100:80), i.e., (89.75 Kg ha^{-1}). Phosphorus uptake was lowest in the control group (1.76 kg ha^{-1}). NPK 170:130:100 had the maximum potassium uptake (kg ha^{-1}) with a value of 124.96 followed by NPK (150:100:80), which had a value of 116.59 kg ha^{-1}.

Table 03: Economics of different treatments in the second year after transplanting of Pyrethrum.

Treatment	Cost of Cultivation	Gross return ha^{-1} (INR)	Net return ha^{-1} (INR)	B:C ratio
Control	45000	171000	126000	3.80
NPK (60:60:20)	62000	290400	228400	4.68
NPK (80:70:30)	76000	365800	289800	4.81
NPK (100:80:40)	91000	441200	350200	4.85
NPK (120:90:50)	103000	501000	398000	4.86
NPK (150:100:60)	115000	436800	321800	3.80
Mean	82000	367700	285700	4.47
SEM (±)	0.00	10,498.190	10,498.190	0.14
CD at 0.05 level	0.001	33,507.948	33,507.948	0.44

Market price of dried Pyrethrum flowers (kg^{-1}): Rs. 1500/-

Table 04: Nutrient uptake as influenced by different doses of NPK.

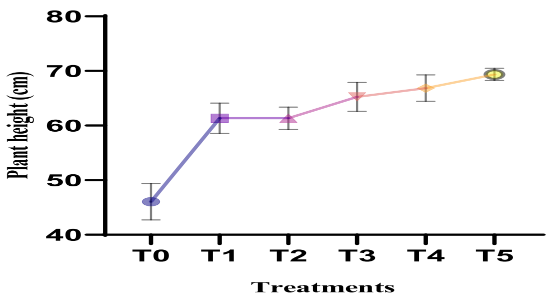
Treatment	Nutrient uptake (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium
Control	8.57	1.76	24.36
NPK (60:30:20)	108.52	63.26	93.08
NPK (90:50:40)	125.66	72.51	104.71
NPK (120:70:60)	134.11	81.51	109.84
NPK (150:100:80)	142.83	89.75	116.59
NPK (170:130:100)	164.27	98.25	124.96
Mean	113.93	67.84	95.59
SEM (±)	0.032	0.059	0.012
CD at 0.05 level	0.103	0.189	0.039

Findings suggest that the NPK level of 120:90:50 is the best combination to obtain the highest dry flower yield (310.49 kg ha^{-1}) in the lower hills of Uttarakhand. However, the fresh flower weight obtained was highest under NPK level 100:80:40, i.e., 840.47 kg ha^{-1}, but its dry flower yield estimated was 301.93 kg ha^{-1} which was the second highest yield after 310.49 kg ha^{-1}. This could be due to the difference in moisture levels in the fresh flowers at the time of harvesting. Experimental research performed in the same location in the year 2014-15 and 2015-16 suggests that the best NPK ratio for higher flower yield is 100:120:60, which reveals that phosphorus plays an important role in flowering (Rao *et al*., 1983).

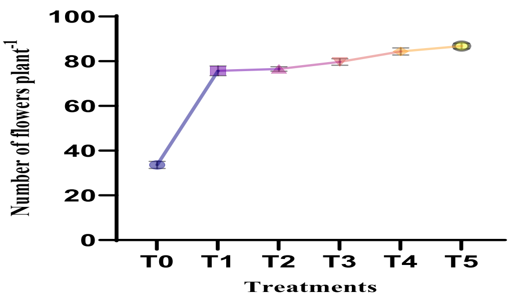
Table 05: Multiple comparisons of dry flower yield ha^{-1}

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Control	NPK (60:60:20)	-149.893	65.4149	0.269	-369.617	69.830
	NPK (80:70:30)	-130.187	65.4149	0.400	-349.910	89.537
	NPK (100:80:40)	-158.760	65.4149	0.221	-378.484	60.964
	NPK (120:90:50)	-167.320	65.4149	0.182	-387.044	52.404
	NPK (150:100:60)	-149.600	65.4149	0.270	-369.324	70.124
NPK (60:60:20)	Control	149.893	65.4149	0.269	-69.830	369.617
	NPK (80:70:30)	19.707	65.4149	1.000	-200.017	239.430
	NPK (100:80:40)	-8.867	65.4149	1.000	-228.590	210.857
	NPK (120:90:50)	-17.427	65.4149	1.000	-237.150	202.297
	NPK (150:100:60)	.293	65.4149	1.000	-219.430	220.017
NPK (80:70:30)	Control	130.187	65.4149	0.400	-89.537	349.910
	NPK (60:60:20)	-19.707	65.4149	1.000	-239.430	200.017
	NPK (100:80:40)	-28.573	65.4149	0.997	-248.297	191.150
	NPK (120:90:50)	-37.133	65.4149	0.991	-256.857	182.590
	NPK (150:100:60)	-19.413	65.4149	1.000	-239.137	200.310
NPK (100:80:40)	Control	158.760	65.4149	0.221	-60.964	378.484
	NPK (60:60:20)	8.867	65.4149	1.000	-210.857	228.590
	NPK (80:70:30)	28.573	65.4149	.997	-191.150	248.297
	NPK (120:90:50)	-8.560	65.4149	1.000	-228.284	211.164
	NPK (150:100:60)	9.160	65.4149	1.000	-210.564	228.884
NPK (120:90:50)	Control	167.320	65.4149	0.182	-52.404	387.044
	NPK (60:60:20)	17.427	65.4149	1.000	-202.297	237.150
	NPK (80:70:30)	37.133	65.4149	0.991	-182.590	256.857
	NPK (100:80:40)	8.560	65.4149	1.000	-211.164	228.284
	NPK (150:100:60)	17.720	65.4149	1.000	-202.004	237.444
NPK (150:100:60)	Control	149.600	65.4149	0.270	-70.124	369.324
	NPK (60:60:20)	-.293	65.4149	1.000	-220.017	219.430
	NPK (80:70:30)	19.413	65.4149	1.000	-200.310	239.137
	NPK (100:80:40)	-9.160	65.4149	1.000	-228.884	210.564
	NPK (120:90:50)	-17.720	65.4149	1.000	-237.444	202.004

Based on observed means. The error term is Mean Square (Error) =6418.670.



(A)



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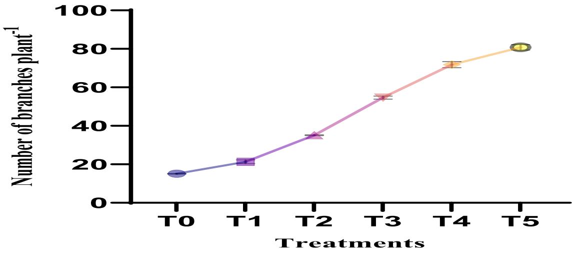

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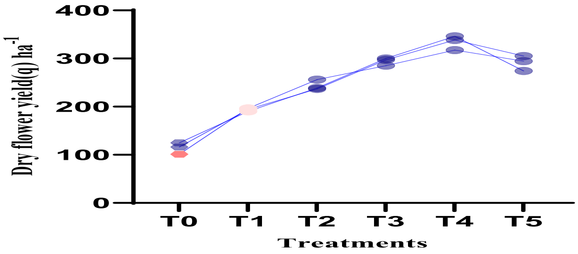

(D)

Figure 01: **(A) Plant height (cm) of Pyrethrum at harvesting stage (B) Number of flower plant^{-1} at harvesting stage (C) Number of branches plant^{-1} at harvesting stage (D) Dry flower yieldha^{-1} (Kg); Treatments =T; (T_0; Control, $T_{1;}$ NPK (60:60:20), T_2; NPK (80:70:30), T3; NPK (100:80:40), T4; NPK (120:90:50), $T_{5,}$ NPK (150:100:60).Statistical Values are presented in Table 01. & 02, replicated value are included in graphical representation.**

(A)

(B)

Figure 02: **(A) Dried flowers under different treatments of NPK levels; (B) Growth and size of fresh flowers under different treatments of NPK levels, T0 (control), T1 (60:60:20), T2 (80:70:30), T3 (100:80:40), T4 (120:90:50) and T5 (150:100:60).**

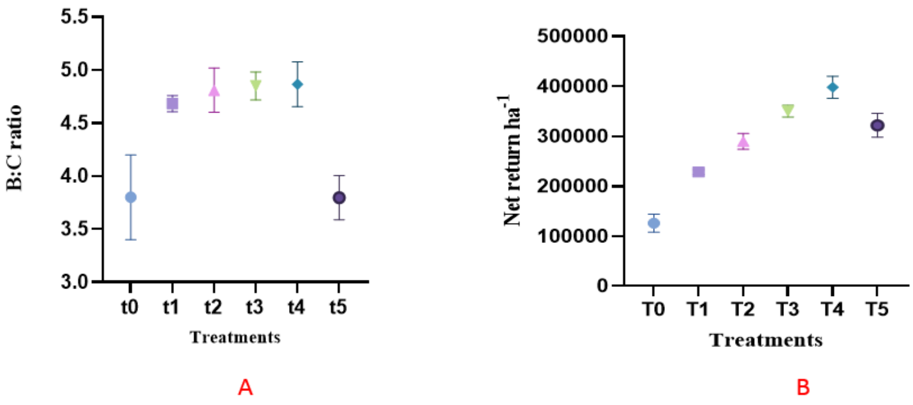

Figure 03: **(A) B:C ratio (B) Net return ha^{-1} Treatments =T; (T0; Control, T1; NPK (60:60:20), T2; NPK (80:70:30), T3; NPK (100:80:40), T4; NPK (120:90:50), T5, NPK (150:100:60). Statistical Values are presented in Table 3, replicated value are included in graphical representation.**

Wandahwa *et al*., 1996, stated that the application of 40 and 80 kg ha^{-1} phosphate significantly increased the plant diameter and number of flowers over no phosphorus application. However, application beyond 120 kg ha^{-1} phosphate did not give significant results. N and K additions did not alter flower yield or pyrethrin concentration. The pyrethrin concentration was unaffected by the amount of phosphorus applied. This finding also supported the earlier findings by Hussain *et al.* 1976; and Pinkerton, 1971.

CONCLUSIONS

Pyrethrum cultivation in hilly regions of India has great potential, given the favorable environment and growing demand for Pyrethrin. While research efforts have been made to promote this crop, there is still a lack of data on the appropriate amount of nutrients needed for optimal growth, particularly for ratoon crops. To address this, our study aimed to determine the ideal NPK levels for maximum dry flower yield, Pyrethrin concentration, and yield, while also maximizing net returns and the B:C ratio. Through our research, we found that the most suitable NPK level was 120:90:50, resulting in a yield of 334 kg/ha, Pyrethrin concentration of 1.35%, and yield of 4.51 kg/ha. Our findings will greatly benefit efforts to promote Pyrethrum cultivation in India's hilly regions, providing valuable insights into best practices for optimal crop growth and yield.

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Conflicts of Interest

All authors have no conflicts of interest to declare.

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