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Effect of Leaf Cuttings and Nutrient Levels on Growth, Yield and Quality of Seed in Palak (*Beta vulgaris* var. *bengalensis*)

SHUBHAM MALVIYA[1], SS KUSHWAH[1]*, RK SHARMA[1] AND BK KACHOULI[2]

[1]Department of Vegetable Science, [2]Department of Genetics and Plant Breeding
College of Horticulture, Mandsaur, Madhya Pradesh-458002, India

*kushwahhort@gmail.com

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ABSTRACT: A field investigation was conducted at Bahadari Farm, College of Horticulture, Mandsaur (MP) during the Rabi, 2021-22. Twelve treatment combinations comprising of three leaf cutting levels viz., C_1 (No cutting), C_2 (One cutting) and C_3 (two cuttings) and four nutrient levels viz., F_1 (No Fertilizer), F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O), F_3 (75 kg N+60 kgP_2O_5+45kgK_2O) and F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O) were tested in factorial randomized block design with three replications. Observations were recorded on plant height, number of leaves, leaf area per plant, fresh and dry weight of shoot per plant, number of spikes per plant, length of spike, number of seed per spike, leaf yield, seed yield, germination, test weight, seedling vigour index-I and seedling vigour index-II. Economics of different treatments was calculated in terms of gross and net return as well as benefit: cost ratio. The findings of the experiment revealed that number of leaf cuttings, nutrient levels as well as their combined effect had significant effect on all the growth, yield and seed quality parameters but no effect on plant height, number of leaves, length of spike and seedling vigour index-I which indicated non significant influence of combined effect of leaf cuttings and nutrient levels. Highest leaf yield (136.11/ha) was noted with C_3F_4 which was at par with the C_3F_3 (117.77q/ha). Rest of the treatments had significantly lower leaf yield as compared to C_3F_4. Application of C_2F_3 had recorded highest seed yield (25.23q/ha) which was at par with C_2F_4 (24.87q/ha). Rest of the treatments had significantly lower seed yield as compared to C_2F_3. Highest gross return (Rs. 691300), net return (Rs.647155) as well as B:C ratio(14.66) were realized with C_2F_3.

Keywords: Palak, *Beta vulgaris* var. *bengalensis*, leaf cuttings, nutrient levels

INTRODUCTION

Palak, also known as spinach beet (*Beta vulgaris* var. *bengalensis*), is one of the most common leafy vegetables most widely grown in the states of Uttar Pradesh, West Bengal, Punjab, Haryana, Delhi, Madhya Pradesh, Gujarat and Maharashtra. It is very rich in minerals and vitamin A and C. It also contains good amounts of protein, calcium, iron and roughages thus, making it highly useful in human diet. Palak is more important amongst all leafy vegetables owing to its shortest crop period. Palak leaves are valued for their medicinal properties. The leaves are used in inflammation, paralysis, headache and is a remedy for diseases of spleen and liver. It also acts as a mild laxative besides other medicinal properties [1]. Palak is a herbaceous annual, cultivated for its edible leaf, while it is a biennial crop in case of seed production. In the early stages of the plant growth (at vegetative phase), it produces rosette, succulent edible leaves on a small thick stem. The inflorescence emerges either in the axils of the leaf or from a terminal bud from the main shoot as well as from the lateral shoots [2].

The demand for quality seed of good palak varieties for better leaf yield is growing. The growth and yield of leaves as well as seed of palak in a particular area depend on the genetic constitution of the cultivar, environmental factors and adoption of improved agro-techniques. Among the improved agro techniques, use of fertilizers, and number of leaf cuttings affect the leaf and seed yield potential most significantly [1]. For obtaining more vegetative growth, cutting of leaves at right stages is important as it promotes the side shoots arise which increases the number of leaves per plant and ultimately increase the yield [3, 4]. However, the requirements for seed production are different. Among various production technologies providing proper nutrition and cuttings are important for the higher seed yield with better quality. Mane *et al*. [5] stated that more cuttings may reduce the seed yield in palak, though taking a few cuttings of green

leaves serve as a source of additional income. Singh *et al.* [6] reported that number of cuttings had a pronounced effect on both leaf yield, seed yield and its quality components.

Nutrients play an important role in determining the plant growth and development. Nitrogen, phosphorus and potassium are primary nutrients required in larger quantity and affects growth, yield and quality of seed in palak. Application of proper dose of these nutrients is an important task which enables to realize their maximum benefits. Not much work has been carried out on this aspect in palak with regard to seed production. The fertilizer requirement of the crop may vary due to various factors such as plant variety, climatic conditions, soil types, nutrient availability, moisture supply and other economic reasons. The balanced application of NPK fertilizers has great effect on growth and productivity of crop plants. Nitrogen and phosphorus are important components for different essential organic compounds such as nucleic acids, amino acids, proteins, enzymes, vitamins and many other compounds which are required for diverse physiological and biochemical processes that comprise the several stages of plant growth and development. Potassium also plays a vital role in plant-water relations, regulating many plant metabolic processes through its important role in the activation of necessary enzyme reactions and amelioration of quality attributes through speeding up the translocation of assimilates and other solutes from plant leaves to edible plant parts [7]. Keeping in view the above, an experiment was conducted with the objectives to study the effect of leaf cuttings and nutrient levels on growth, yield and quality of seed and to work out the economics of different treatments for seed production of palak.

MATERIAL AND METHODS

A field investigation was conducted at Bahadari Farm, College of Horticulture, Mandsaur (MP) during *Rabi*, 2021-22. Twelve treatment combinations comprising of three leaf cutting levels viz., C_1 (no cutting), C_2 (one cutting) and C_3 (two cuttings) and four nutrient levels viz., F_1 (no fertilizer), F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O), F_3 (75 kg N+60 kgP_2O_5+45kgK_2O) and F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O) were tested in factorial randomized block design with three replications. Fertilizers were applied as per the treatments. One third dose of nitrogen and full dose of phosphorus and potash was given at the time of sowing below the seed placement depth. Remaining quantity of nitrogen was applied in two equal split doses. Nitrogen was applied in the form of urea and di-ammonium phosphate (DAP), phosphorus was applied in the form of DAP and potassium given in the form of muriate of potash (MOP).The soil of the experimental field was medium black (Vertisol) clay in texture with soil pH of 7.6, electrical conductivity 0.42 dSm^{-1}, 139.60 kg/ha of available nitrogen, 14.5 kg/ha of available phosphorus and available potash 429.70 kg/ha. Healthy seed of palak variety Pusa Bharti were sown on 29th November 2021. Seeds were treated with Mancozeb @2g + carbendazim @ 1g/kg seeds. The sowing of seeds was done in lines at a distance of 60 cm row to row and 10 cm from plant to plant. Four to five seeds were sown per hill to ensure the desired plant population. After 12 days of sowing, thinning of extra plants was done keeping one plant per hill in order to maintain optimum plant population. Observations were recorded on plant height at harvesting stage, number of leaves at flowering stage, leaf area per plant at flowering stage, fresh and dry weight of shoot per plant at harvesting stage, number of spikes per plant, length of spike, number of seed per spike, leaf yield, seed yield, germination, test weight, seedling vigour index-I and seedling vigour index-II. Economics of different treatments was worked out in terms of gross and net return as well as benefit: cost ratio. The data recorded during the experiment were statistically analyzed as per standard procedure as suggested by Panse and Sukhatme [8].

RESULTS AND DISCUSSION

Effect of leaf cutting on growth parameters

Data indicated (Table 1) that leaf cuttings had significant effect on plant height in palak. Highest plant height was measured with C_1 (No cutting) which was followed by C_2 (One cutting) with non-significant difference. Lowest plant height was observed under C_3 (two cuttings). Adverse effect of leaf cutting on plant height was also observed by [9, 10,11]. There was significant effect of leaf cuttings on number of leaves per plant. Highest number of leaves per plant were recorded with C_1 (no cutting) which was at par with C_2 (one cutting). The difference between C_1 and C_2 was non-significant but both were significantly superior over C_3 (two cuttings). These findings are in agreement with Naik et al. [1] and Bharad et al. [3]. Leaf cuttings had imposed significant influence on leaf area per plant in palak. Maximum leaf area per plant was recorded with treatment C_1 (no cutting) which was significantly higher than both C_2 and C_3. It was followed by C_2 (one cutting). The minimum leaf area per plant

Table 1. Effect of leaf cuttings, nutrient levels and their interactions on growth parameters in palak

Treatment	Plant height (cm) at harvesting stage	Number of leaves at flowering stage	Leaf area (cm^2) at flowering stage	Fresh weight of plant (g) at harvesting stage	Dry weight of plant (g) at harvesting stage
Effect of leaf cuttings (C)					
C_1	186.42	79.65	2306.43	268.42	85.35
C_2	183.92	74.48	1916.38	230.33	83.07
C_3	170.50	70.13	1620.79	201.17	71.03
S.Em±	3.30	1.80	92.05	7.13	1.23
CD at 5%	9.68	5.27	269.97	20.90	3.60
Effect of nutrient levels (F)					
F_1	156.69	64.98	1435.61	178.44	57.04
F_2	178.49	72.24	1679.78	214.56	75.39
F_3	191.02	78.07	2229.66	256.11	91.50
F_4	194.91	83.73	2446.41	284.11	95.33
S.Em±	3.81	2.07	106.29	8.23	1.42
CD at 5%	11.18	6.08	311.73	24.13	4.15
Combined effect (C×F)					
C_1F_1	162.87	67.93	1488.03	190.67	60.33
C_1F_2	184.93	75.53	1769.30	233.33	78.37
C_1F_3	198.33	84.27	2867.67	305.67	99.90
C_1F_4	199.53	90.87	3100.70	344.00	102.80
C_2F_1	161.73	63.73	1463.90	174.67	58.30
C_2F_2	183.20	72.13	1721.30	214.33	76.93
C_2F_3	194.47	80.67	2142.70	261.67	96.70
C_2F_4	196.27	81.40	2337.60	270.67	100.33
C_3F_1	145.47	63.27	1354.90	170.00	52.50
C_3F_2	167.33	69.07	1548.73	196.00	70.87
C_3F_3	180.27	69.27	1678.60	201.00	77.90
C_3F_4	188.93	78.93	1900.93	237.67	82.87
S.Em±	6.60	3.59	184.10	14.25	2.45
CD at 5%	NS	NS	539.94	41.79	7.20

was observed with C_3 (two cuttings). Similar findings have also been reported earlier [12]. Leaf cutting has imparted significant effect on fresh weight of shoot per plant in palak. There was reduction in fresh weight of shoot per plant with increasing the number of cuttings. Highest fresh weight per plant was recorded with treatment C_1 (no cutting) which was significantly higher over rest of the treatments. Leaf cutting has affected the dry weight of shoot per plant significantly. Highest dry weight of plant was observed with treatment C_1 (no cutting) which was at par with C_2 (one cutting). Lowest dry weight of shoot per plant was found with C_3 (two cuttings) which differed significantly from both C_1 and C_2. Higher number of leaves and leaf area facilitated more photosynthesis and accumulation of food material resulting in higher dry weight of shoot per plant.

Effect of nutrient levels on growth parameters

There was significant effect of nutrient levels on plant height in palak (Table 1). Maximum plant height was recorded with F_4 (100kg N + 80kg P_2O_5 + 60kg K_2O) which was at par to F_3 (75kg N + 60kg P_2O_5 + 45kg K_2O). Rest of the treatments had significantly lower plant height as compared to both F_4 and F_3. Lowest plant height was observed under F_1 (no fertilizers) treatment. These results are in conformity with the findings of Wahocho *et al.* [13] and Islam *et al.* [14]. There was significant increase in number of leaves with increasing nutrient levels up to F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O). Further increase in nutrient level F_4 (100kg N + 80kg P_2O_5 + 60kg K_2O) had no significant impact on number of leaves per plant. The difference between F_4 and F_3 was non-significant but both were significantly superior over F_2 and F_1. Higher number of leaves with higher nutrient levels might be due higher availability of nutrients particularly nitrogen which encourages vigorous vegetative growth [9, 15]. Leaf area per plant reflected significant effect of nutrient levels in palak. Maximum leaf area per plant was measured with F_4 treatment (100 kg N+80 kg P_2O_5+60 kg K_2O) which was followed by F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O)

and F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O). Minimum leaf area per plant was measured with the F_1 treatment (no fertilizer). The difference between F_4 and F_3 was non-significant but both these treatments were significantly superior over F_2 and F_1. Increase in leaf area might be due to the availability of nutrients which are essential for formation of protoplasm and leads to more cell division and cell enlargement ultimately more number of leaves and larger size. These results are in line with the findings of Bharad *et al.* [3] and Abgad *et al.* [16].

Application of different nutrient levels exerted significant impact on fresh and dry weight of shoot per plant. Highest fresh weight per plant was observed with F_4 (100kg N + 80kg P_2O_5 + 60kg K_2O) which was significantly superior over all other nutrient levels. It was followed by F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O) and F_2 (50 kg N+40 kg P_2O_5+30 kg K_2O). Lowest fresh weight per plant was found with the treatment F_1 (no fertilizer). The increase in fresh weight of shoot with the higher nutrient levels may be due to the positive impact of NPK in stimulating different physiological and biochemical activities within plant cells including the processes of photosynthesis and biosynthesis of important organic components that are needed for promoting meristematic activity to generate more cells, tissues and organs bringing high plant growth [17, 18]. Maximum dry weight per plant was recorded under nutrient level F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O) followed by F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O) with non-significant difference. Nutrient level F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O) and F_1 (No Fertilizer) recorded dry weight of shoot in descending order. Both F_1 and F_2 were differed significantly with F_3 and F_4 as well as with each other. Availability of more nutrients enhanced the number of leaf and leaf area thereby photosynthesis which might have lead to more assimilation of carbohydrates resulting in higher dry weight of shoot per plant [17, 18 and 19].

Combined effects of leaf cutting and nutrient levels on growth parameters

Plant height and number of leaves per plant revealed non-significant influence of combined effect of leaf cuttings and nutrient levels in palak (Table 1). Leaf area per plant was affected significantly with combined effect of leaf cuttings and nutrient levels in palak. Maximum leaf area per plant was measured under the treatment C_1F_4 (no cutting +100 kg N+80 kg P_2O_5+60 kg K_2O) which was followed by C_1F_3 (no cutting +75 kg N+60 kg P_2O_5+45 kg K_2O), C_2F_4 (one cutting +100 kg N+80 kg P_2O_5+60 kg K_2O), C_2F_3 (one cutting +75 kg N+60 kg P_2O_5+45 kg K_2O), C_3F_4 (two cuttings +100 kg N+80 kg P_2O_5+60 kg K_2O) and C_1F_2 (no cutting +50 kg N+40 kg P_2O_5+30 kg K_2O). Minimum leaf area per plant was recorded under the treatment combination of C_3F_1 (two cuttings + no fertilizer). The difference between C_1F_4 and C_1F_3 was non-significant but rest of the treatments had significantly lesser leaf area per plant as compared to both of these treatments. Lesser cuttings and higher nutrient levels have lead to increase in leaf area. These findings are corroborated with those reported by Singh *et al*. [9]. Combined effect of leaf cutting and nutrient levels showed significant effect on fresh and dry weight of shoot per plant. Application of C_1F_4 (no cutting +100 kg N+80 kg P_2O_5+60 kg K_2O) had recorded maximum fresh weight per plant which was at par to C_1F_3 (no cutting +75 kg N+60 kg P_2O_5+45 kg K_2O). Rest of the treatments had significantly lower fresh weight of shoot per plant as compared to C_1F_4 (No cutting +100 kg N+80 kg P_2O_5+60 kg K_2O). Minimum fresh weight of shoot per plant was observed under the treatment combination of C_3F_1 (two cuttings + no fertilizer) which was at par to C_2F_1 (one cuttings + no fertilizer) and C_1F_1 (no cutting + no fertilizer). Leaf cutting increased the number of shoot, leaf area which in presence of sufficient nutrients further increased the photosynthesis and assimilation of carbon resulting in more fresh weight of shoot per plant. Highest dry weight of shoot per plant was noted with C_1F_4 (no cutting +100 kg N+80 kg P_2O_5+60 kg K_2O) which was followed by C_2F_4 (one cutting +100 kg N+80 kg P_2O_5+60 kg K_2O), C_1F_3 (no cutting +75 kg N+60 kg P_2O_5+45 kg K_2O) and C_2F_3 (one cutting +75 kg N+60 kg P_2O_5+45 kg K_2O). All these four treatments were statistically at par. Lowest dry weight of shoot per plant was recorded with C_3F_1 (two cuttings + no fertilizer) which was at par to C_2F_1 (one cutting + no fertilizer). Higher photosynthesis due to more leaf area under balanced availability of nutrients might have increased the accumulation of food material in plant resulting in higher dry weight per plant.

Effect of leaf cutting on yield parameters and yield

Findings of the present experiment (Table 2) indicated that number of spikes per plant was influenced significantly with leaf cuttings. Highest number of spikes per plant were counted with C_3 (two cuttings) and C_2 (one cutting) which were at par with respect to number of spikes per plant. Lowest number of spikes per plant were noted with C_1 (no cutting) which differed significantly with both C_2 and C_3. Leaf cutting promoted emergence of more shoots which in turn resulted in more number of spikes

Table 2. Effect of leaf cuttings, nutrient levels and their interactions on yield parameters and yield in palak

Treatment	Number of spikes per plant	Length of spike (cm)	Number of seed/ spike	Leaf yield (q/ha)*	Seed yield (q/ha)
Effect of leaf cuttings (C)					
C_1	10.81	63.49	331.23	0.00 (0.71)	18.10
C_2	13.13	62.16	345.05	56.39 (7.50)	19.20
C_3	13.72	55.43	259.98	110.27 (10.48)	16.15
S.Em±	0.37	1.03	13.82	0.17	0.52
CD at 5%	1.09	3.03	40.54	0.48	1.51
Effect of nutrient levels (F)					
F_1	10.37	44.76	173.65	43.70 (5.59)	10.83
F_2	11.27	59.80	285.39	53.15 (6.14)	16.23
F_3	13.78	67.11	390.21	59.44 (6.44)	22.05
F_4	14.80	69.76	399.09	65.92 (6.75)	22.16
S.Em±	0.43	1.19	15.96	0.19	0.60
CD at 5%	1.26	3.50	46.81	0.56	1.75
Combined effect (C×F)					
C_1F_1	9.87	46.75	180.81	0.00 (0.71)	12.65
C_1F_2	10.73	63.27	349.55	0.00 (0.71)	17.31
C_1F_3	10.80	70.23	406.06	0.00 (0.71)	21.43
C_1F_4	11.83	73.71	388.49	0.00 (0.71)	21.02
C_2F_1	10.60	45.21	177.19	45.55 (6.78)	10.62
C_2F_2	11.47	62.93	292.07	57.78 (7.62)	16.07
C_2F_3	14.60	69.39	474.81	60.55 (7.74)	25.23
C_2F_4	15.87	71.11	436.12	61.66 (7.85)	24.87
C_3F_1	10.63	42.33	162.94	85.55 (9.27)	9.22
C_3F_2	11.60	53.19	214.56	101.66 (10.11)	15.30
C_3F_3	15.93	61.72	289.76	117.77 (10.87)	19.50
C_3F_4	16.70	64.48	372.65	136.11 (11.68)	20.59
S.Em±	0.74	2.07	27.64	0.33	1.03
CD at 5%	2.18	NS	81.07	0.97	3.03

*values given in parentheses are square root transformed values of leaf yield

per plant. Data indicated that leaf cutting has significant effect on length of spike in palak. Longest spikes were observed with C_1 (no cutting) and C_2 (one cutting) which was followed by C_3 (two cuttings). The difference between C_1 and C_2 was non- significant but both have significantly longer spikes as compared to C_3. Higher number of cutting might have reduced the stored food material per shoot which lead to lesser growth of spike as compared to plants in which no leaf cutting was done. There was significant influence of leaf cutting on number of seed per spike. Highest number of seed per spikes were counted with C_2 (one cutting) which was followed by C_1 (no cutting) and C_3 (two cuttings). Treatment C_1 was at par to C_1 but both were significantly superior over C_3. Higher number of shoots as compared to C_1 and longer spikes than C_3 along with better fruit setting might have lead to highest number of seeds per spike under C_2. Highest leaf yield was recorded with C_3 (two cuttings) which was significantly superior over C_2 (one cutting). No leaf yield was obtained with C_1 (no cutting). Increase in leaf yield with increasing number of cutting showed multiple and shoot growth encouragement effect of cutting. The results are in conformity with the findings of Mane *et al.* [5]. Leaf cutting imposed significant influence on seed yield in palak. Highest seed yield was recorded with C_2 (one cutting) and C_1 (no cutting) followed by C_3 (two cuttings). The difference between C_1 and C_2 was non-significant but both were significantly superior over C_3. One leaf cutting promoted more shoots thereby more number of spikes as compared to no cutting. But more number of cuttings resulted into reduction of seed yield due to smaller spikes, delay in flowering and seed setting as well as having less number of seed. These results are in agreement with those of Narayan *et al.* [4] and Rana *et al.* [20].

Effect of nutrient levels on yield parameters and yield

Nutrient levels had imposed significant effect on number of spikes per plant, length of spike, number of seed per spike, leaf and seed yield in palak (Table 2). There was significant increase in number of spikes per plant with increasing nutrient level up to F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O). Further increase in nutrient level i.e. F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O) had showed non-significant improvement in number of spikes per plant over F_3. Application of F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O) registered highest number of spikes per plant which was followed by F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O), F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O) and F_1 (no fertilizer). The difference between F_4 and F_3 was non-significant but both were significantly superior over F_2 and F_1. Balanced availability of nutrients encourages emergence of inflorescence which might be the reason for higher number of spikes under F_3 as compared to over nutrition in case of F_4 which promoted more vegetative growth and comparatively lower nutrition under F_2 and F_1 which has reduced growth and lesser food accumulation leading to lesser spikes per plant. Longest spikes were found with use of F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O) which was followed by F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O), F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O) and F_1 (no fertilizer). The difference between F_4 and F_3 was non-significant but both were significantly superior over F_2 and F_1. Higher number of seed per spike was observed with F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O) which was at par with F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O), followed by F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O) and F_1 (no fertilizer). Nutrient levels F_3 and F_4 were significantly superior over F_2 and F_1. More availability of nutrients encouraged accumulation of more photosynthates which might have resulted in longer spikes and formation of more number of seeds per spike. Highest leaf yield was found with F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O). It was followed by F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O), F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O) and F_1 (no fertilizer). The difference between F_4 and F_3 was non-significant. Leaf yield might have increased due to more availability of nutrients which are the important constituents of plant metabolites such as fat, protein and enzyme and encourages vigorous vegetative growth. Similar results have been reported by Singh *et al.* [9], Abgad *et al.* [16] and Darshan *et al.* [21]. Highest seed yield was recorded with application of F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O) and F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O) followed by F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O) and F_1 (no fertilizer) in that order. Higher number of spikes, more number of seeds per spike due to higher nutrient levels further lead to higher seed yield. These findings are in agreement with Islam *et al.* [14].

Combined effects of leaf cutting and nutrient levels on yield parameters and yield

Leaf cutting and nutrient levels had exerted significant influence on number of spikes per plant, number of seed per spike, leaf and seed yield in palak. Length of spike indicated non significant influence of combined effect of leaf cutting and nutrient levels in palak (Table 2). Highest number of spikes per plant were recorded with C_3F_4 (two cuttings +100 kg N+80 kg P_2O_5+60 kg K_2O), C_3F_3 (two cuttings +75 kg N+60 kg P_2O_5+45 kg K_2O), C_2F_4 (one cutting +100 kg N+80 kg P_2O_5+60 kg K_2O) and C_2F_3 (one cutting +75 kg N+60 kg P_2O_5+45 kg K_2O). All these four treatments were statistically at par with one another but significantly superior over rest eight treatments in the study. Lowest number of spikes per plant was recorded with C_1F_1 (no cutting + no fertilizer). More number of shoots due to leaf cutting along with higher availability of nutrients might have encouraged the emergence of more number of spikes per plant. Highest number of seed per spike was noted with C_2F_3 (one cutting +75 kg N+60 kg P_2O_5+45 kg K_2O), C_2F_4 (one cutting +100 kg N+80 kg P_2O_5+60 kg K_2O) and C_1F_3 (no cutting +75 kg N+60 kg P_2O_5+45 kg K_2O). These three treatments were at par to one another. Rest of the treatments recorded significantly lesser number of seed per spike. Longer spikes and better fruit setting under C_2F_3 due to moderate leaf cutting and balanced nutrition might have resulted in highest number of seed per spike. There was increase in leaf yield with increasing number of cuttings and nutrient levels. Highest leaf yield was noted with C_3F_4 (two cuttings +100 kg N+80 kg P_2O_5+60 kg K_2O) and C_3F_3 (two cuttings +75 kg N+60 kg P_2O_5+45 kg K_2O) which were at par with each other. Rest of the treatments had significantly lower leaf yield as compared to C_3F_4. These findings are in line with the results of Moniruzzaman and Rahman [22], Mondal *et al.* [23] and Singh *et al.* [24]. Application of C_2F_3 (one cutting +75 kg N+60 kg P_2O_5+45 kg K_2O) had recorded highest seed yield followed by C_2F_4 (one cutting +100 kg N+80 kg P_2O_5+60 kg K_2O) with non-significant difference. Rest of the treatments had significantly lower seed yield as compared to C_2F_3. Lowest seed yield was registered with C_3F_1 (two cuttings + no fertilizer) which was at par to C_2F_1 (one cutting + no fertilizer) but significantly lower than all other treatments in the investigation. The results

are in agreement with the findings of Moniruzzaman and Rahman [22] and Singh *et al.* [24].

Effect of leaf cutting on seed quality parameters

Leaf cutting exerted significant effect on germination, test weight, seedling vigour index-I and seedling vigour index-II in palak (Table 3). Highest seed germination was noted with C_1 (no cutting) which was at par with C_2 (one cutting) and significantly higher than C_3 (two cuttings). Higher germination could be the result of effective synthesis and translocation of photosynthates from source to sink leading to better formation of embryo. These findings uphold the view of Narayan *et al*. [4] and Singh *et al*. [6]. Highest test weight was noted under C_1 (no cutting) which was at par with C_2 (one cutting), followed by C_3 (two cuttings). Reduction in seed weight with increasing levels of cuttings could be attributed to reduced plant height and leaf area resulting in less availability and translocation of photosynthates responsible for seed development. These findings corroborated the findings of Singh *et al.* [6] and Rana *et al.* [20]. Highest seedling vigour index-I was obtained with C_1 (no cutting) and C_2 (one cutting) followed by C_3 (two cuttings). The difference between C_1 and C_2 was non-significant but both these treatments were significantly superior over C_3. Similar findings have been reported by Singh *et al.* [6]. Highest seedling vigour index-II was found with C_1 (no cutting). The difference in seedling vigour index-II under C_1 and C_2 was non-significant but both these treatments showed significantly higher seedling vigour index-II as compared to C_3. These results are in line with the findings of Singh *et al.* [6].

Effect of nutrient levels on seed quality parameters

Findings of the experiment (Table 3) indicated that nutrient levels had significant influence on seed germination, test weight, seedling vigour index-I and seedling vigour index-II in palak. Highest seed germination was noted with F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O) and F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O) which was followed by F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O) and F_1 (no fertilizer). No

Table 3. Effect of leaf cuttings, nutrient levels and their interactions on seed quality parameters in palak

Treatment	Germination (%)	Test weight (g)	Seedling vigour index-I	Seedling vigour index-II
Effect of leaf cuttings (C)				
C_1	76.55	11.59	736.08	206.81
C_2	74.53	11.28	714.56	196.36
C_3	71.05	10.30	649.50	161.13
S.Em±	1.04	0.13	8.95	3.61
CD at 5%	3.04	0.38	26.25	10.58
Effect of nutrient levels (F)				
F_1	61.56	9.62	525.21	66.01
F_2	75.11	10.48	710.99	167.91
F_3	78.82	11.77	769.01	253.93
F_4	80.68	12.36	794.97	264.55
S.Em±	1.20	0.15	10.33	4.16
CD at 5%	3.51	0.44	30.31	12.21
Combined effect (C×F)				
C_1F_1	63.67	9.94	553.10	78.60
C_1F_2	77.33	10.94	749.47	182.93
C_1F_3	81.00	12.68	812.77	278.27
C_1F_4	84.18	12.82	828.99	287.43
C_2F_1	62.33	9.64	536.28	68.47
C_2F_2	75.67	10.43	729.11	166.47
C_2F_3	79.78	12.46	792.06	269.36
C_2F_4	80.33	12.60	800.78	281.13
C_3F_1	58.67	9.29	486.24	50.97
C_3F_2	72.33	10.07	654.38	154.33
C_3F_3	75.67	10.17	702.20	214.17
C_3F_4	77.52	11.67	755.16	225.07
S.Em±	2.07	0.26	17.90	7.21
CD at 5%	6.07	0.76	NS	21.15

significant difference was observed between F_4 and F_3 but both of these nutrient levels were significantly superior over rest two treatments. This may be due to proper development of seed and adequate availability of nutrients that might have helped in producing bolder and heavier seeds [14, 25 and 26]. Application of F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O) had recorded highest test weight which was followed by F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O), F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O) and F_1 (no fertilizer) in that order. These findings are corroborated the results obtained by Islam *et al.* [14] and Biradar *et al.* [25]. Highest seedling vigour index-I was observed with F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O) which was at par with F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O) followed by F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O) and F_1 (no fertilizer). Nutrient level F_4 (100 kg N+80 kg P_2O_5+60 kg K_2O) had recorded highest seedling vigour index-II which was at par with F_3 (75 kg N+60 kg P_2O_5+45 kg K_2O) followed by F_2 (50 kg N+40 kg P_2O_5+ 30 kg K_2O) and F_1 (no fertilizer). Better seed development with higher nutrition resulting in higher germination and better seedling growth may be reason of higher seedling vigour index-II with higher nutrient levels [25].

Combined effect of leaf cutting and nutrient levels on seed quality parameters

In the present study (Table 3) combined effect of leaf cutting and nutrient levels was found to be non significant influence on seed germination and seedling vigour index-I in palak, while test weight and seedling vigour index-II showed significant influence of combined effect of leaf cutting and nutrient levels. Highest test weight was recorded with C_1F_4 (no cutting +100 kg N+80 kg P_2O_5+60 kg K_2O), C_1F_3 (no cutting +75 kg N+60 kg P_2O_5+45 kg K_2O), C_2F_4 (one cutting +100 kg N+80 kg P_2O_5+60 kg K_2O) and C_2F_3 (one cutting +75 kg N+60 kg P_2O_5+45 kg K_2O). All these treatments were at par with each other. Rest of the treatments had significantly lower test weight as compared to these. Lowest test weight was noted with C_3F_1 (two cuttings + no fertilizer). Similar findings were reported by Moniruzzaman and Rahman [22]. Highest seedling vigour index-II was recorded with C_1F_4 (no cutting +100 kg N+80 kg P_2O_5+60 kg K_2O), C_2F_4 (one cutting +100 kg N+80 kg P_2O_5+60 kg K_2O), C_1F_3 (no cutting +75 kg N+60 kg P_2O_5+45 kg K_2O) and C_2F_3 (one cutting + 75 kg N+60 kg P_2O_5 + 45 kg K_2O). All these treatments were statistically at par with one another but significantly superior over rest of the treatments. Lowest seedling vigour index-II was noted with C_3F_1 (two cuttings + no fertilizer) which was at par to C_2F_1 (one cutting + no fertilizer). Higher test weight due to no cutting and higher nutrition further encouraged better seed germination and growth of seedlings resulting in higher seedling vigour index-II.

Economics of different treatments

The findings (Table 4) revealed that highest gross return was obtained with C_2F_3 (one cutting +75 kg N+60 kg P_2O_5+45 kg K_2O) which was followed by C_2F_4 (one cutting +100 kg N+80 kg P_2O_5+60 kg K_2O), C_3F_4 (two cuttings +100 kg N+80 kg P_2O_5+60 kg K_2O) and C_3F_3 (two cuttings +75 kg N+60 kg P_2O_5+45 kg K_2O). Lowest gross return was realized with C_2F_1 (one cutting + no fertilizer). Highest net return was recorded with C_2F_3 (one cutting +75 kg N+60 kg P_2O_5+45 kg K_2O) which was followed by C_2F_4 (one cutting +100 kg N+80 kg P_2O_5+60 kg K_2O), C_3F_4

Table 4. Effect of leaf cuttings and nutrient levels on the economics of the palak seed production (per hectare)

Treatment	Total cost (Rs)	Gross return (Rs)	Net return (Rs)	B: C ratio
C_1F_1	36300.00	316250.00	279950.00	7.71:1
C_1F_2	39528.37	432750.00	393221.63	9.95:1
C_1F_3	41144.59	535750.00	494605.41	12.02:1
C_1F_4	42757.15	525500.00	482742.85	11.29:1
C_2F_1	39300.00	311050.00	271750.00	6.91:1
C_2F_2	42528.37	459530.00	417001.63	9.81:1
C_2F_3	44144.59	691300.00	647155.41	14.66:1
C_2F_4	45757.15	683410.00	637652.85	13.94:1
C_3F_1	42300.00	316050.00	273750.00	6.47:1
C_3F_2	45528.37	484160.00	438631.63	9.63:1
C_3F_3	47144.59	605270.00	558125.41	11.84:1
C_3F_4	48757.15	650860.00	602102.85	12.35:1

The selling price of palak leaves – Rs.1000/q, Seed selling price of palak seed – Rs.25000/q

(two cuttings +100 kg N+80 kg P_2O_5+60 kg K_2O) and C_3F_3 (two cuttings +75 kg N+60 kg P_2O_5+45 kg K_2O). Lowest net return was obtained with C_2F_1 (one cutting + no fertilizer). Highest B : C ratio was realized with C_2F_3 (one cutting +75 kg N+60 kg P_2O_5+45 kg K_2O) which was followed by C_2F_4 (one cutting +100 kg N+80 kg P_2O_5+60 kg K_2O), C_3F_4 (two cuttings +100 kg N+80 kg P_2O_5+60 kg K_2O) and C_1F_3 (no cutting +75 kg N+60 kg P_2O_5+45 kg K_2O). Lowest B : C ratio was obtained with C_3F_1 (two cuttings + no fertilizer). These results are in conformity with the findings of Islam *et al.* [14] and Sarkar *et al.* [27].

CONCLUSION

Considering the growth and yield parameters, seed quality attributes as well as economics obtained under different treatments during present investigation, it is concluded that one leaf cutting, and application of 75 kg N+60 kg P_2O_5+45 kg K_2O kg/ha is the most suitable treatment for economical seed production of palak in the Malwa region of Madhya Pradesh.

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DECLARATION

Authors have no conflict of interest.

REFERENCES

1. NAIK DM, SB PATIL, SD JATURE, AND SJ SHINDE (2009). Effect of sowing dates and number of leaf cuttings on growth and yield of palak (*Beta vulgaris* L.). *The Asian Journal of Horticulture*, **4**(2): 377-379.
2. NATH PREM AND KRM SWAMY (2016). A Text Book of Vegetable Crops. ICAR New Delhi, pp-337-339.
3. BHARAD SG, SNEHAL D KORDE, PRAVINA SATPUTE AND MN BAVISKAR (2013). Effect of organic manures and number of cuttings on growth, yield and quality of Indian spinach. *The Asian Journal of Horticulture*, **8**(1): 60-64.
4. NARAYAN SUMATI, AJAZ MALIK, MI MAKHDOOMI, AMBREEN NABI, K HUSSAIN, AND FA KHAN (2018). Influence of date of sowing and number of cuttings on leaf yield and quality of seed in palak (*Beta vulgaris* var. *bengalensis*). *Journal of Experimental Agriculture International*, **24**(3): 1-4.
5. Mane SV, HD Bodake, PD Dalve and KA Jadhav (2008). Effect of spacing and number of leaf cuttings on green yield and seed yield of palak cv. Pusa Jyoti. *The Asian Journal of Horticulture*, **3**(2): 412-414.
6. SINGH RAJENDER, GEETA BASSI, AND DILBAG SINGH (2013). Influence of sowing time and leaf cuttings on the seed yield and quality components of palak (*Beta vulgaris* var. *bengalensis*). *Indian Journal of Agricultural Sciences*, **83**(4): 410–414.
7. EL-SAADY WALEED A (2016). Spinach (*Spinacia oleracea* L.) growth, yield and quality response to the application of mineral NPK fertilizer ratios and levels. *Middle East Journal of Agriculture Research*, **5**(4): 908-917.
8. PANSE VG AND PV SUKHATME (1985). *Statistical Methods for Agricultural Workers*. ICAR, New Delhi.
9. SINGH GYANENDRA PRATAP, ML MEENA, AND JAY PRAKASH (2015). Effect of different levels of nitrogen and cuttings on growth, leaf yield and quality of spinach beet *(Beta vulgaris* var. *bengalensis)* cv. All Green. *European Journal of Biotechnology and Bioscience*, **3**(6): 38-42.
10. ZODGE SD, UY PURANIK, VD KAPSE AND SB DODAKE (2017). Effect of factory effluent and inorganic fertilizers on growth, yield and ascorbic acid content at various cuttings of spinach (*Beta vulgaris var. bengalensis*) in lateritic soil of Konkan (M.S.). *International Journal of Chemical Studies,* **5**(2): 81-85.
11. NAYAK PK AND S MAJI (2018). Response of nutrient and cutting management for quality and green yield of Palak (*Beta vulgaris* var. *bengalensis*). *Journal of Crop and Weed*, **14**(1): 126-129.
12. ABED MY AND EF SHEBL (2016). Effect of sowing dates and number of cuttings on yield and quality of spinach (*Spinacia oleraceae* L.). *Journal of Plant Production*, *Mansoura University*, **7**(12): 1437-1442.
13. WAHOCHO NA, N MEMON, MN KANDHRO, TF MIANO, KH TALPUR, AND SA WAHOCHO (2016). Response of nitrogen on the growth and productivity of spinach (*Spinacia oleracea* L.). *Sindh University Research Journal (Science Series)*, **48**(2): 305-308.
14. ISLAM MD RAFIQUL, KHALEDA KHATUN, TAHMINA MOSTARIN, MD EHSANUL HAQ, MD NAHIDUL ISLAM, BITHI RANI BISWAS AND JINIA AFSUN (2019). Effect of nitrogen and phosphorus on the growth and seed yield of spinach. *Asian Plant Research Journal,* **3**(1): 1-9.
15. ZAMAN QAMAR-UZ, FS HAMID, SHAMS-UL ISLAM, FAYAZ AHMAD AND NAVEED AHMAD (2018). Impact of various levels of nitrogen and phosphorus on growth and yield of spinach (*Spinacea oleracea* L.) under conditions of Mansehra (Pakistan). *Open Academic Journal of Advanced Science and Technology*, **2**(1): 5-8.
16. ABGAD NILESH P, OMMALA D KUCHANWAR, PRITI R SHIRSAT, SAGAR N INGLE AND SAINATH G ZALTE (2015). Effect of phosphorus and potassium levels on and quality of spinach. *Asian Journal of Soil Science*, **10**(2): 248-251.
17. ALI H AISHA, M MAGDA HAFEZ, R ASMAA MAHMOUD AND MR SHAFEEK (2013). Effect of bio and chemical fertilizers on growth, yield and chemical properties of spinach plant (*Spinacia oleracea* L.). *Middle East Journal of Agriculture Research,* **2**(1): 16-20.
18. FOUDA KARIM FIKRY (2016). Quality parameter and chemical composition of spinach plant as affected by mineral fertilization and selenite foliar application. *Egyptian Journal of Soil Science*, **56**(1): 149-167.

19. HAFEZ MAGDA M, MR SHAFEEK, ASMAA R MAHMOUD AND AISHA H ALI (2015). Beneficial effects of nitrogen fertilizer and humic acid on growth, yield and nutritive values of spinach (*Spinacia olivera* L.). *Middle East Journal of Applied Sciences*, **5**(2): 597- 603.

20. RANA SC, VK PANDITA AND SANJAI SIROHI (2015). Influence of spacing and number of leaf cuttings on seed yield in fenugreek. *Legume Research*, **38**(6): 858-860.

21. DARSHAN SN, NM VIJAYKUMAR, VRASHABH GOURAJ, GC VINAY AND CM SHANKARA MURTHY (2019). Effect of varying levels of nitrogen on growth and yield of spinach (*Spinacia olearacea*). *Journal of Emerging Technologies and Innovative Research*, **6**(6): 305-310.

22. MONIRUZZAMAN M AND MM RAHMAN (2015). Effect of nitrogen level and leaf cutting frequency on foliage and seed yields of coriander. *Bangladesh Journal of Agricultural Research*, **40**(1): 53-60.

23. MONDAL REVA, UMESH THAPA, SATISH KR SUBBA AND DEEPSIL GURUNG (2017). Optimisation of nitrogen level and cutting interval for growth and yield of *Ipomoea reptans*. *International Journal of Agriculture Environment and Biotechnology*, **10**(1): 25-29.

24. SINGH SATYBHAN, VK DHANGRAH, VIRENDRA SINGH, OVS THENUA, KRISHAN PAL AND RD SHUKLA (2018). Nitrogen rate and cutting management for fenugreek green leaf and seed production. *International Journal of Bio-resource and Stress Management*, **9**(4): 523-526.

25. BIRADAR VIVEK, BS VYAKARANHAL, M SHEKHAR-GOUDA, SD SHASHIDHARA AND PR DHARMATTI (2006). Effect of plant nutrition and spacing on seed quality of palak cv. All Green. *Karnataka Journal of Agricultural Sciences,* **19**(1): 127-130.

26. ZAKI MS AND SS HALAWA (2016). Effect of nitrogen fertilizer and growth stimulants on flowering behaviour, seed yield and its quality of spinach. *Annals of Agricultural Sciences, Moshtohor*, **54**(2): 345-354.

27. SARKER ASHOKA, ABUL MD KASHEM AND KHAN TOWHID OSMAN (2014). Influence of lime and phosphorus on growth performance and nutrient uptake by Indian spinach (*Basella alba* L.) grown in soil. *Open Journal of Soil Science*, **4**: 98-102.