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Effect of nutrient and weed management on growth and productivity of field pea [*Pisum sativum* L. var. *arvense*]

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Abstract
In order to study the effect of different nutrient and weed management practices a field experiment, entitled "Effect of Nutrient and Weed management on growth and productivity of field pea (*Pisum sativum* L. var. *arvense*)" was conducted at the Agricultural Research Farm (Department of Agronomy), Raja Balwant Singh College, Bichpuri (Agra) during *Rabi* seasons of 2021-22 and 2022-23 with the objectives, to study the effect of nutrient management on growth and productivity of field pea, to find out the suitable nutrient and weed management for field pea and to study the economic feasibility of the treatments. Experiment was laid out using two factor *viz*., main plot treatments (4): NM_0-Control, NM_1-100% RDF (20:40:20 NPK kg ha^{-1}), NM_2-75% RDF + 2 t FYM ha^{-1}, NM_3-75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* and sub plot treatments (5): WM_0-Unweeded, WM_1-Weed free, WM_2-Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 Hand weeding at 30 DAS, WM_3-Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS, WM_5-Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS. Highest productivity of field pea have been achieved with the application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* with weed control using pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 Hand weeding at 30 DAS and the maximum net returns was fetched when nutrient management was done by application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* and weeds were controlled with pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 Hand weeding at 30 DAS. But, Maximum B: C ratio was fetched when nutrient management was done by application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*, (2.06, 2.27 and 2.16) and weeds were controlled by Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS, (2.16, 2.36 and 2.26), during first year, second year and pooled respectively.

Keywords: Pea, field pea, weed, herbicide, nutrient management and weed management

Introduction
Pulse crops are wonderful gift of the nature. They provide nutrition's food, fodder and thrive well in fragile ecosystem where other crops often fail. Pulses have the ability to fix atmospheric nitrogen in their root nodules in association with *Rhizobium* bringing qualitative improvement in physical, chemical and biological properties of soil. Pulses are next to cereals in term of their economic importance as human food. The ability of pulses to fix atmospheric nitrogen in the soil crop system is their unique and beneficial characteristic among all the plant species, pulses can contribute significantly to achieve the twin objective of increasing productivity and improving the sustain ability of rice and wheat-based cropping systems. India has undergone a series of ups and down in agricultural production with the climatic condition playing have in the years of abnormality. We faced many droughts in 18^{th} and 19^{th} centuries without much knows how to counterfeit late middle years of 20^{th} century. India has improved its position in food grain production with technological interventions. Currently, agro-eco systems are facing the problems of over exploitation of natural resources, decline in soil fertility, ground water level and agricultural productivity. Hence, ensuring sustainable food security is the need of the hour. Pulses play an important role in providing a nutritionally balanced diet. These are the principal source of protein for vegetarians. India is the world's largest producer with 25% share in the global production.
Pulses are important for the nutritional security point of view of the cereal based vegetarian diet of large scale of country. India is the largest producer, consumer and importer of pulses in the world. It has been projected that 32 million tonnes of total pulse requirement for the burgeoning

population of India, which will grow to 1.69 billion by 2050. To attain up to this level an annual growth rate of 2.2% is required. The demand for pulses continues to grow at 2.8% per annum. Although challenges are diverse including climate changing scenario, decreasing land and water resources, this target is not unattainable. Increasing the average productivity of pulses to > 1200 kg ha^{-1} and bringing an additional area of about 3.5 million hectare under pulses cultivation will be a concrete step in this direction. Enhancement of yield through development of input responsive varieties with multiple resistances to diseases and insect-pests, short duration varieties that fit well in different cropping systems and climate resilient varieties of pulses will be enormously helpful in a vertical expansion of pulses in the country. Similarly, development of new plant types for different agro-climatic situations and development of photo-thermo insensitive cultivars in crops like filed pea, urdbean and moongbean will help expanding the areas of these crops in the non-traditional areas of the country (Yadav *et al.*, 2019) [27]. Pulses are rich source of protein (20 to 25%), ability to fix atmospheric nitrogen (30-150 kg ha^{-1}) and consistent source of income and employment to small and marginal farmers; and thus hold a premier position in the world agriculture. The United Nations declared 2016 as “International Year of pulses” with the objectives of increasing production and consumption of pulses by 10% by 2020 and creating awareness of benefits of pulses by utilizing social media. In India, pulses constitute a group of 12 crops that include mainly pigeonpea (*Cajanus cajan* L.), chickpea (*Cicer arietinum* L.), mungbean (*Vigna radiata* L. *Wilczek*), urdbean (*Vigna mungo* L. *Hepper*), lentil (*Lens culinaris* L.) and field pea (*Pisum sativum* L.). Field pea, one of the important pulse crop of winter season has great potential to contribute to the pulse basket in India. It provides protein rich food for majority of Indians. The major constraints that hinder the realization of potential yield of field pea in our country are well known. These include unavailability of the quality seeds of improved varieties in required quantities, traditional cultivation practices, inadequate supply of nutrients, improper weed management, biotic and abiotic stresses prevailing in the field pea growing areas besides the social and economic factors, the integrated approach of nutrient supply by chemical fertilizers along with bio-fertilizers is gaining importance, as this system not only reduces the excessive use of inorganic fertilizers, but also sustains the crop productivity by improving soil health besides being an environment friendly approach. Integration of inorganic fertilizers and biofertilizers resulted in better growth, yield and nutrient uptake in field pea. This study was aimed to evaluate the effect of integrated application of bio-fertilizers and inorganic (Jackson, 1993) [11].

Integrated crop management is one of the ways which increases the production as well as sustainability. Amongst the different agro-techniques required to raise the production of field pea, a timely carried out crop management has emerged as one of the major constraints of production. In recent years due to increased labour cost and their non-availability for weeding, insect-pest and disease management at peak requirement, the use of integrated crop management in field pea is indispensable. Integrated crop management is a pragmatic approach to the production of crops. Unlike integrated pest management which focuses on crop protection, integrated crop management includes more aspects. Yield of field pea can be increased by adopting improved varieties, fertilizer management, weed management, integrated pest management module (Ali and Kumar, 2007) [3].

Phosphorus is one of the essential nutrients for plant growth and development. Phosphorus regulates protein synthesis in plants, because it is a component of the complex nucleic acid structure, phosphorus is important in cell division and development of new tissue also phosphorus plays a vital role in plant energy reactions, photosynthesis, respiration, genetic transfer, seed and fruit production and nutrient transfer in plants. Phosphorus is also component of phytin a major storage form of P in seeds, phospholipids and ATP. Moreover, phosphorus promotes root growth and stimulants tillering and often fertilizers are mainly determined by the soil P available but are not related to soil organic matter, total N, total P, soil $CaCo_3$ contents and soil N available. Despite the potential for field pea crops in agriculture they still face challenges due to competition from weeds and insects and due to lack of successful nodulation.

Integrated weed management became an accepted and frequently used term by weed scientist in the early 1970’s.

An integrated weed management may be defined as the combination of two or more weed-control methods at low input levels to reduce weed competition in a given cropping system below the economical threshold level. IWM involves the utilization of a combination of mechanical, chemical, cultural and biological practices of weed management in a planned sequence, so designed as not to affect the ecosystem. IWM is a science-based decision-making process that co-ordinates the use of environmental information, weed biology and ecology, all available technologies to control weeds by the most economical means, while posing the least possible risk to people and the environment. The information on nutrient and weed management of pulses especially on field pea is quite meager. Therefore, to understand the integrated crop management in relation to field pea variety for maximization of yield, the experiment was conducted at the Agricultural Research Farm of Raja Balwant Singh College, Bichpuri (Agra) during *Rabi* seasons of 2021-22 and 2022-23 to study the effect of nutrient and weed management on growth and productivity of field pea (*Pisum sativum* L. var. *arvense*).

Methods and Materials

The present field experiment, entitled “Effect of Nutrient and Weed management on growth and productivity of field pea (*Pisum sativum* L. var. *arvense*)” was conducted at the Agricultural Research Farm (Department of Agronomy), Raja Balwant Singh College, Bichpuri (Agra) during *Rabi* seasons of 2021-22 and 2022-23 with the objectives, to study the effect of nutrient management on growth and productivity of field pea, to find out the suitable nutrient and weed management for field pea and to study the economic feasibility of the treatments. Agricultural Research Farm, of Raja Balwant Singh College, Agra which is situated at the distance of about 11 km away from Agra city on Agra-Bharatpur road at an elevation (altitude) of 163.4 metre above mean sea level with 27.2^{o} N latitude and 77.9^{o} E longitude with all required facilities for cultivation of above mentioned experiment crop. The region has a semi-arid and sub – tropical climate with hot and dry summers and severe cold winters. The soil of the experimental field was gangetic alluvial with calcareous layer at the depth of about 1.5 m to 2.0 m and was well drained. To know the exact nature and physico-chemical properties of the experimental soil, a composite soil sample from the surface of soil (0-15 cm depth) was taken before application of fertilizers and sowing of the experimental plot with the help of an auger and subjected to mechanical and chemical analysis. Soil of experimental site was deficient in available total nitrogen (N), low in organic carbon; medium in available phosphorus (P_2O_5) and fairly rich in potassium (K_2O)

content and the soil was slightly alkaline in reaction. Experiment was laid out using two factor *viz.*, main plot treatments (4): NM_0-Control, NM_1-100% RDF (20:40:20 NPK kg ha^{-1}), NM_2-75% RDF + 2 t FYM ha^{-1}, NM_3-75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* and sub plot treatments (5): WM_0-Unweeded, WM_1-Weed free, WM_2-Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 Hand weeding at 30 DAS, WM_3-Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS, WM_5-Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS. The seed material of variety Jay (KPMR-522) was sown @ 80 kg ha^{-1} (120 g sub^{-1} plot) in furrows 30 cm apart of the depth of 7-10 cm with the help of kudali and was covered by light planking. Above ground plant parts harvested from net plot area including the grain and straw were carefully bundled, tagged and taken to the threshing floor separately. The individual bundle was weighed after complete drying in the sun before threshing and weighed in kg $plot^{-1}$ then converted in to quintal ha^{-1} by multiplying with conversion factor *i.e.* 10.416. Total biomass of net plot was threshed out by manual labour and grains were separated by winnowing and weighed in kg $plot^{-1}$ then converted in to quintal ha^{-1} by multiplying with conversion factor *i.e.* 10.416. This calculated by subtracting grain yield (q ha^{-1}) from total biological yield (q ha^{-1}). Harvest index was calculated as per the formula suggested by Donald (1962) [9].

Results

Growth characters

The data pertaining to the germination count, crop stand $running^{-1}$ metre, plant height (cm) and no. of primary branches $plant^{-1}$ is presented in table 1 (a). Germination counts were influenced significantly due to different nutrient management practices. Highest germination counts (9.13, 9.30 & 9.21) were recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3). Among treatments, application of NM_2 (75% RDF + 2 t FYM ha^{-1}) was found at par in comparison to NM_1 (100% RDF) at 30, 60 DAS and 90 DAS, except 120 DAS and at harvest, however, the lowest count (6.93, 7.10 & 7.01) were recorded under control treatment (NM_0) during both the year of study. Weed management practices also influenced germination count significantly during both the year of experimentation.

Table 1 (a): Growth of field pea as influenced by nutrient and weed management

Treatments	Notations	Germination count running^{-1} metre			Crop stand running^{-1} metre			Plant height (cm)			No. of primary branches plant^{-1}		
		2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
A. Main plot – Nutrient Management													
1. Control (No nutrient)	NM_0	6.93	7.10	7.01	8.13	8.09	8.11	59.13	59.46	59.29	2.33	2.64	2.48
2. 100% RDF (20:40:20 NPK kg ha^{-1})	NM_1	8.46	8.60	8.53	8.86	8.80	8.83	67.33	67.66	67.49	3.53	3.76	3.64
3. 75% RDF + 2 t FYM ha^{-1}	NM_2	7.93	8.06	7.99	8.60	8.58	8.59	63.00	63.20	63.10	2.93	3.36	3.14
4. 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*	NM_3	9.13	9.30	9.21	9.46	9.40	9.43	69.00	69.53	69.26	4.00	4.34	4.17
SE(m)±		0.06	0.09	0.04	0.06	0.05	0.05	0.53	0.53	0.52	0.07	0.10	0.06
C. D. (P = 0.05)		0.24	0.32	0.16	0.23	0.19	0.19	1.86	1.89	1.86	0.26	0.38	0.24
B. Sub plot – Weed Management													
1. Unweeded	WM_0	6.75	6.95	6.85	7.75	7.62	7.68	63.41	63.66	63.53	1.91	2.14	2.02
2. Weed free	WM_1	9.25	9.41	9.33	9.66	9.64	9.65	65.83	66.33	66.08	4.33	4.93	4.63
3. Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 Hand weeding at 30 DAS	WM_2	8.50	8.62	8.56	9.25	9.20	9.22	65.33	65.75	65.54	3.91	4.14	4.02
4. Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS	WM_3	8.33	8.45	8.39	8.91	8.90	8.90	64.75	64.08	64.41	3.25	3.80	3.52
5. Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS	WM_4	7.75	7.87	7.81	8.25	8.21	8.23	63.75	64.00	63.87	2.58	2.62	2.60
SE(m)±		0.11	0.16	0.11	0.08	0.10	0.08	0.50	0.61	0.55	0.11	0.13	0.08
C.D. (P = 0.05)		0.33	0.29	0.31	0.24	0.25	0.25	1.45	1.77	1.59	0.32	0.33	0.24

Highest germination counts (9.25, 9.41 & 9.33) were recorded under weed free treatment (WM_1) whereas unweeded treatment recorded lowest germination count (6.75, 6.95 & 6.85). Among herbicides treatments, application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum germination count, WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) was found at par in comparison to WM_2. WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) was found non- significant in comparison to WM_1, WM_2 and WM_3 during both the year of study. Crop stand were influenced significantly due to different nutrient management practices.

Highest crop stand were recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3), however, the lowest crop stand were recorded under control treatment (NM_0) at all the stages of crop growth (30, 60, 90, 120 DAS and at harvest). Among treatments, application of NM_2 (75% RDF + 2 t FYM ha^{-1}) at par in comparison to NM_1 (100% RDF) at 30, 60 DAS and 90 DAS except 120 DAS and at harvest during both the year of study. Pooled data follow the same trend at all the stages of crop growth, highest crop stand were recorded under weed free treatment (WM_1) whereas unweeded treatment recorded lowest crop stand.

Among herbicides treatments, application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum crop stand, WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) was found at par in comparison to WM_2 (Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS) at 30, 60 DAS and 90 DAS *fb* WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) during both the year of experimentation. Pooled data follow the same trend at all the stages of crop growth. Plant height was influenced significantly due to different nutrient management practices. Highest plant height was recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) *fb* NM_1 (100% RDF) and NM_2 (75% RDF + 2 t FYM ha^{-1}) at all the stages of plant height during both the year of study.

Table 1 (b): Growth of field pea as influenced by nutrient and weed management

Treatments	Notations	Growth characters								
		No. of secondary branches plant^{-1}			Fresh weight plant^{-1} (g)			Dry matter accumulation plant^{-1} (g)		
		2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
A. Main plot – Nutrient Management										
1. Control (No nutrient)	NM_0	8.90	8.99	8.94	46.34	50.24	48.26	38.53	41.66	40.10
2. 100% RDF (20:40:20 NPK kg ha^{-1})	NM_1	11.06	11.22	11.14	52.66	56.42	54.54	43.80	46.79	45.29
3. 75% RDF + 2 t FYM ha^{-1}	NM_2	9.90	10.08	9.99	50.18	53.94	52.06	41.73	44.74	43.23
4. 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*	NM_3	12.00	12.15	12.07	57.62	60.7	59.16	47.93	50.33	49.14
SE(m)±		0.13	0.14	0.10	0.61	0.59	0.55	0.61	0.51	0.48
C. D. (P = 0.05)		0.39	0.52	0.36	2.16	2.08	1.94	2.16	1.80	1.72
B. Sub plot – Weed Management										
1. Unweeded	WM_0	9.71	9.83	9.77	42.5	47.09	44.78	35.33	39.05	37.20
2. Weed free	WM_1	11.06	11.26	11.16	57.1	59.50	58.30	47.50	49.33	48.41
3. Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 Hand weeding at 30 DAS	WM_2	10.83	10.97	10.90	55.9	58.21	57.05	46.50	48.27	47.39
4. Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS	WM_3	10.61	10.75	10.68	52.5	56.64	54.55	43.66	46.97	45.30
5. Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS	WM_4	10.10	10.23	10.16	50.5	55.18	52.85	42.00	45.77	43.89
SE(m)±		0.12	0.15	0.10	0.69	0.73	0.67	0.69	0.68	0.60
C. D. (P = 0.05)		0.35	0.43	0.32	2.01	2.11	1.97	2.01	1.68	1.75

Highest plant height was recorded under weed free treatment (WM_1) whereas unweeded treatment recorded minimum plant height. Among herbicide treatments, application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum plant height, WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) was found at par in comparison to WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) at 90 DAS, WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) and WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) were found at par in comparison to WM_2 (Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS) at 120.

Table 2: Root development studies of field pea as influenced by nutrient and weed management practices at initiation of 50 to 75% flowering

Treatments	Notations	Root development studies								
		Length of main root (cm)			Number of primary roots plant^{-1}			Number of effective nodules plant^{-1}		
		2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
A. Main plot – Nutrient Management										
1. Control (No nutrient)	NM_0	3.50	3.71	3.61	6.46	6.80	6.63	13.06	13.28	13.17
2. 100% RDF (20:40:20 NPK kg ha^{-1})	NM_1	4.78	5.24	5.01	9.00	9.60	9.30	16.53	17.05	16.79
3. 75% RDF + 2 t FYM ha^{-1}	NM_2	4.18	4.49	4.33	7.73	8.33	8.03	15.86	16.35	16.10
4. 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*	NM_3	5.26	5.78	5.52	9.53	10.46	9.99	17.06	17.75	17.40
SE(m)±		0.17	0.22	0.09	0.28	0.26	0.24	0.25	0.29	0.12
C. D. (P = 0.05)		0.63	0.77	0.32	0.99	0.93	0.85	0.90	1.02	0.96
B. Sub plot – Weed Management										
1. Unweeded	WM_0	3.50	3.89	6.69	7.58	8.25	7.91	14.08	14.40	14.24
2. Weed free	WM_1	4.99	5.47	5.23	8.91	9.66	9.28	16.83	17.42	17.12
3. Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 Hand weeding at 30 DAS	WM_2	4.98	5.30	5.14	8.58	9.16	8.87	16.41	16.97	16.69
4. Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS	WM_3	4.47	4.88	4.67	8.08	8.68	8.38	15.66	16.12	15.89
5. Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS	WM_4	4.14	4.49	4.31	7.75	8.25	8.00	15.16	15.64	15.40
SE(m)±		0.20	0.20	0.12	0.33	0.31	0.23	0.31	0.35	0.24
C. D. (P = 0.05)		0.59	0.59	0.32	0.97	0.98	0.97	0.98	1.04	0.69

DAS and at harvest during both the year of experimentation. Pooled data follow the same trend at all the stages of crop growth. Number of primary branches plant^{-1} was influenced significantly except at 30 DAS due to different nutrient management treatments. Maximum primary branches plant^{-1} were recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (100% RDF) except at 90 DAS and NM_2 (75% RDF + 2 t FYM ha^{-1}), however, the minimum primary branches plant^{-1} were observed under control treatment (NM_0) at all the stages of crop growth, NM_1 (100% RDF) was found at par in comparison to NM_3 (75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*) at 90 DAS during both the year of study. Pooled data follow the same trend at all the stages of crop growth. Maximum number of primary branches plant^{-1} were recorded under weed free treatment (WM_1) whereas unweeded treatment recorded the minimum primary branches plant^{-1}. Among herbicides treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum primary branches plant^{-1}. Application of WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) was found at par in comparison to WM_2 (Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS) at 90 DAS and 120 DAS *fb* WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) during both the year of experimentation. Pooled data follow the same trend at all the stages of crop growth. Number of secondary branches plant^{-1} were influenced due to different nutrient management treatments.

The data pertaining to the no. of secondary branches plant^{-1}, fresh weight plant^{-1} (g) and dry matter accumulation plant^{-1} (g) is presented in table 1 (b). Maximum secondary branches plant^{-1} were recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (100% RDF) and NM_2 (75% RDF + 2 t FYM ha^{-1}), NM_1 (100% RDF) and NM_2 (75% RDF + 2 t FYM ha^{-1}) were found at par in comparison to NM_3 (75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*) at 60 DAS. However, the minimum secondary branches plant^{-1} were observed under control treatment (NM_0) at all the stages of crop growth during both the year of study, weed management practices also influenced number of secondary branches plant^{-1} significantly at all the stages of crop growth during both year of experimentation. Maximum number of secondary branches plant^{-1} were recorded under weed free treatment (WM_1) which was found at par with application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2), WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) was found at par in comparison to WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) at 30 DAS and 60 DAS, WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) was found at par in comparison to WM_2 (Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS) at 90, 120 DAS and at harvest. Whereas unweeded treatment recorded the minimum secondary branches plant^{-1} during both the year of experimentation. Pooled data follow the same trend at all the stages of crop growth. Highest fresh weight was recorded with the application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (100% RDF) and NM_2 (75% RDF + 2 t FYM ha^{-1}), however, the lowest fresh weight (g plant^{-1}) was recorded under control treatment (NM_0) at all the stages of crop growth during both Highest fresh weight was recorded under weed free treatment (WM_1) whereas unweeded treatment recorded lowest fresh weight (g plant^{-1}). Among herbicides treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum fresh weight, WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) was found at par in comparison to WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS), WM_3 was found at par in comparison to WM_2 (Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS) at all the stages of crop growth during both the year of experimentation. Pooled data follow the same trend at all the stages of crop growth. Dry matter accumulation by pea crop was influenced significantly due to different nutrient management practices.

Highest dry matter accumulation was recorded with the application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (100% RDF) and NM_2 (75% RDF + 2 t FYM ha^{-1}), however, the lowest dry matter accumulation was recorded under control treatment (NM_0) at all the stages crop growth during both the year of study. Treatment NM_3 recorded an increment of 24.39, 20.81 and 22.54% during first year, second year and pooled, respectively, at harvest stage over control treatment. Pooled data follow the same trend at all the stages of crop growth, the highest dry matter accumulation was recorded under weed free treatment (WM_1) whereas unweeded treatment recorded lowest dry matter accumulation. Among herbicide treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum dry matter accumulation which was found at par with WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) and WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) during both the year of experimentation. Treatment WM_1 recorded an increment of 34.44, 26.32 and 30.13% during first year, second year and pooled, respectively, at harvest stage over unweeded treatment (WM_0). Among herbicide treatments, WM_2 accumulated 31.61, 23.63 and 27.39% more dry matter during first year, second year and pooled, respectively, over unweeded treatment. Pooled data follow the same trend at all the stages of crop growth.

The data pertaining to the root development studies *viz.*, length of main root (cm), number of primary roots plant^{-1} and number of effective nodules plant^{-1} is presented in table 2. Nutrient management practices have influenced the length of main root (cm) of pea crop. The maximum length of main root (5.26, 5.78 & 5.52 cm) was recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) which remain at par with NM_1 (100% RDF) followed by NM_2 (75% RDF + 2 t FYM ha^{-1}), however, the minimum length of main root (3.50, 3.71 & 3.61 cm) was recorded under control treatment (NM_0) at initiation of 50 to 75% flowering during first year, second year and pooled respectively, of study, maximum length of main root (4.99, 5.47 & 5.23 cm) was recorded under weed free treatment (WM_1) which was found at par with Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) and WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS). Minimum length of main root (3.50, 3.89 & 6.69 cm) was recorded under unweeded plots at initiation of 50 to 75% flowering during first year, second year and pooled respectively, of experimentation, number of primary roots plant^{-1} was influenced significantly due to different nutrient management practices. Highest number of primary roots plant^{-1} (9.53, 10.46 & 9.99) were recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) which was at par with NM_1 (100% RDF) and NM_2 (75% RDF + 2 t FYM ha^{-1}), however, the lowest number of primary roots plant^{-1} (6.46, 6.80 & 6.63) were recorded under control treatment (NM_0) at initiation of 50 to 75% flowering during first year, second year and pooled respectively, of experimentation. The highest number of primary roots plant^{-1} (8.91, 9.66 & 9.28) were recorded under weed free treatment (WM_1) whereas unweeded treatment recorded the lowest number of primary roots plant^{-1} (7.58, 8.25 & 7.91). Among herbicides treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum number of primary roots plant^{-1} which was found at par with WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) *fb* WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) at initiation of 50 to 75% flowering during first year, second year and pooled respectively, of experimentation.

Number of effective nodules plant^{-1} were influenced significantly due to different nutrient management practices. The maximum number of effective nodules plant^{-1} (17.06, 17.75 & 17.40) were recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3), NM_2 (75% RDF + 2 t FYM ha^{-1}) was found at par in comparison to NM_1 (100% RDF), however, the minimum number of effective nodules plant^{-1} (13.06, 13.28 & 13.17) were recorded under control treatment (NM_0) at initiation of 50 to 75% flowering during first year, second year and pooled respectively, of experimentation, maximum number of effective nodules plant^{-1} (16.83, 17.42 & 17.12) were recorded under weed free treatment (WM_1) whereas unweeded plots recorded minimum effective nodules plant^{-1} (14.08, 14.40 & 14.24). Among herbicides treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* +

1 hand weeding at 30 DAS (WM_2) recorded maximum number of effective nodules Plant^{-1} which was found at par with WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) *fb* WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) at initiation of 50 to 75% flowering during first year, second year and pooled respectively, of experimentation.

Yield

Grain yield (q ha^{-1}) of pea was influenced significantly due to different nutrient management practices. The maximum grain yield (20.25, 21.91 & 21.08 q ha^{-1}) were recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (100% RDF) and NM_2 (75% RDF + 2 t FYM ha^{-1}) was found at par with NM_1, however, the minimum grain yield (11.04, 11.69 & 11.36 q ha^{-1}) were recorded under control treatment (NM_0) during first year, second year and pooled respectively. Treatment NM_3 (75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*) produced 83.34, 87.42 and 85.56% more grain yield during first year, second year and as pooled, respectively over control treatment. Weed management practices also influenced grain yield (q ha^{-1}) of pea crop significantly. Maximum grain yield (20.29, 21.42 & 20.85 q ha^{-1}) was recorded under weed free treatment (WM_1) whereas unweeded plots recorded minimum grain yield (10.11, 11.24 & 10.67 q ha^{-1}). Among herbicides treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum grain yield (18.63, 19.75 & 19.19 q ha^{-1}) *fb* WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) and WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) during both the year of study. Treatment WM_1 recorded an increment of 37.88, 36.35 and 37.10% in grain yield during first year, second year and pooled respectively, over unweeded treatment (WM_0).

Table 3: Productivity of field pea as influenced by nutrient and weed management

Treatments	Notations	Grain yield (q ha^{-1}) 2021-22	Grain yield 2022-23	Grain yield Pooled	Straw yield (q ha^{-1}) 2021-22	Straw yield 2022-23	Straw yield Pooled	Biological yield (q ha^{-1}) 2021-22	Biological yield 2022-23	Biological yield Pooled	Harvest Index (%) 2021-22	Harvest Index 2022-23	Harvest Index Pooled
A. Main plot – Nutrient Management													
1. Control (No nutrient)	NM_0	11.04	11.69	11.36	34.42	35.16	34.79	45.46	46.85	46.15	24.28	24.95	24.61
2. 100% RDF (20:40:20 NPK kg ha^{-1})	NM_1	16.49	17.80	17.14	35.68	36.29	35.98	52.17	54.09	53.13	31.60	32.90	32.25
3. 75% RDF + 2 t FYM ha^{-1}	NM_2	15.97	16.81	16.39	35.54	36.19	35.86	51.51	53.00	52.25	31.00	31.71	31.35
4. 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*	NM_3	20.25	21.91	21.08	38.90	39.47	39.18	59.15	61.38	60.26	34.23	35.69	34.96
SE(m)±		0.26	0.33	0.21	0.32	0.35	0.43	0.81	0.89	0.64	0.28	0.46	0.22
C. D. (P = 0.05)		0.93	1.18	0.75	1.15	1.23	1.54	2.86	3.14	2.27	1.01	1.62	1.31
B. Sub plot – Weed Management													
1. Unweeded	WM_0	10.11	11.24	10.67	32.68	33.35	33.01	42.79	44.59	43.69	23.62	25.20	24.41
2. Weed free	WM_1	20.29	21.42	20.85	38.71	39.38	39.04	59.00	60.8	59.9	34.38	35.23	34.80
3. Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 Hand weeding at 30 DAS	WM_2	18.63	19.75	19.19	38.16	38.84	38.50	56.79	58.59	57.69	32.80	33.70	33.25
4. Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS	WM_3	15.35	16.50	15.92	37.08	37.73	37.40	52.43	54.23	53.33	29.27	30.42	29.84
5. Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS	WM_4	12.82	13.86	13.34	32.78	33.54	33.16	45.6	47.4	46.5	28.11	29.24	28.67
SE(m)±		0.45	0.45	0.40	0.91	0.99	0.82	1.14	1.19	0.64	0.55	0.90	0.46
C. D. (P = 0.05)		1.30	1.66	1.57	2.63	2.86	2.38	3.31	3.44	3.21	1.59	1.62	1.33

Among herbicide treatments, WM_2 (Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS), WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) and WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) produced (84.27, 75.71 and 79.85%), (51.82, 46.79 and 49.20%) and (26.80, 23.30 and 25.02%) more grain yield, respectively, over unweeded treatment during first year, second year and as pooled.

The maximum straw yield (38.90, 39.47 & 39.18 q ha^{-1}) were recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (100% RDF), NM_2 (75% RDF + 2 t FYM ha^{-1}) and NM_0 (control) was found at par with NM_1 (100% RDF), however, the minimum straw yield (34.42, 35.16 & 34.79 q ha^{-1}) were recorded under control treatment (NM_0). Treatment NM_3 produced 13.01, 12.25 and 12.61% more straw yield during first year, second year and as pooled, respectively over control treatment.

The highest straw yield (38.71, 38.38 & 39.04 q ha^{-1}) was obtained under weed free treatment (WM_1) which was found at par with WM_2 (Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS), whereas, unweeded plots recorded minimum straw yield (32.68, 33.35 & 33.01 q ha^{-1}). Among herbicides treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum straw yield (38.16, 38.84 & 38.50 q ha^{-1}) which was found at par with WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) *fb* WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) during first year, second year and pooled. Treatment WM_1 (weed free) recorded an increment of 18.45, 18.08 and 18.26% in straw yield during first year, second year and pooled, respectively, over unweeded treatment (WM_0). Among herbicide treatments, WM_2 accumulated 16.76, 16.46 and 16% more straw yield during first year, second year and pooled, respectively, over unweeded treatment.

The maximum biological yield (59.15, 61.38 & 60.26 q ha^{-1}) was recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (100% RDF), NM_2 (75% RDF + 2 t FYM ha^{-1}) was found at par with NM_1, however, the lowest biological yield (45.46, 46.85 & 46.15 q ha^{-1}) was recorded under control treatment (NM_0) during first year, second year and as pooled. Treatment NM_3 (75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*) produced 30.11, 31.01 and 30.57% more biological yield during first year, second year and as pooled, respectively over control treatment, weed management practices also influenced the biological yield (q ha^{-1}) of pea crop significantly. Highest biological yield (59.00, 60.80 59.90 q ha^{-1}) was recorded under weed free treatment (WM_1) which was found at par with WM_2 (Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS), whereas, unweeded plots recorded minimum biological yield (42.79, 44.59 & 43.69 q ha^{-1}).

Among herbicides treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM$_2$) recorded maximum biological yield (56.79, 58.59 & 57.69 q ha^{-1}) *fb* WM$_3$ (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) and WM$_4$ (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) during both the year of study. Treatment WM$_1$ recorded an increment of 37.88, 36.35 and 37.10% in biological yield during first year, second year and pooled, respectively, over unweeded treatment (WM$_0$), among herbicide treatments, WM$_2$ accumulated 32.71, 31.39 and 32.04% more biological yield during first year, second year and pooled, respectively, over unweeded treatment.

Harvest index (%) were influenced significantly due to different nutrient management practices. The maximum harvest index (34.23, 35.69 & 34.96%) were recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM$_3$) followed by NM$_1$ (100% RDF), NM$_2$ (75% RDF + 2 t FYM ha^{-1}) was found at par with NM$_1$, however, the minimum harvest index (24.28, 24.95 & 24.61%) were recorded under control treatment (NM$_0$) during both the year of study. Treatment NM$_3$ recorded 9.95, 10.74 and 10.35% more harvest index during first year, second year and as pooled, respectively over control treatment, weed management practices also influenced harvest index (%) of pea crop significantly. Maximum value of harvest index (34.38, 35.23 & 34.80%) was found under weed free treatment (WM$_1$) whereas unweeded plots recorded minimum harvest index (23.62, 25.20 & 24.41%). Among herbicides treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM$_2$) recorded maximum value of harvest index (32.80, 33.70 & 33.25%) *fb* WM$_3$ (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS), WM$_4$ (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) was found at par in comparison to WM$_3$ during first year, second year and pooled. Treatment WM$_1$ recorded an increment of 10.76, 10.03 and 10.39% in harvest index during first year, second year and pooled, respectively, over unweeded treatment (WM$_0$), among herbicide treatments, WM$_2$ accumulated 9.18, 8.50 and 8.84% more harvest index during first year, second year and pooled, respectively, over unweeded treatment.

Economics

The highest cost of cultivation (Rs. 32089, 32089 and 32089 ha^{-1}) was involved with treatment NM$_3$ (application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*) followed by NM$_2$ (Rs. 31629, 31629 and 31629) and NM$_1$ (Rs. 28344, 28344 and 28344 ha^{-1}), however, the lowest cost of cultivation (Rs. 25818, 25818 and 25818 ha^{-1}) was estimated under control treatment (NM$_0$) during first year, second year and pooled respectively, of experimentation. Weed management practices also influenced cost of cultivation of field pea crop. Highest cost of cultivation (Rs. 39227, 39227 and 39227 ha^{-1}) was calculated under weed free treatment (WM$_1$) whereas, Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS (WM$_3$) involved lowest cost of cultivation (Rs. 24754, 24754 and 24754 ha^{-1}). Among herbicide treatments, application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM$_2$) recorded highest cost of cultivation (Rs. 31142, 31142 and 31142 ha^{-1}) followed by WM$_4$ (Rs. 26457, 26457 and 26457 ha^{-1}) and WM$_0$ (Rs. 25753, 25753 and 25753 ha^{-1}) during first year, second year and pooled respectively, of experimentation.

Table 4: Economics of field pea as influenced by nutrient and weed management practices

Treatments	Notations	Cost of cultivation (Rs. ha^{-1})			Gross returns (Rs. ha^{-1})			Net returns (Rs. ha^{-1})			B: C ratio		
		2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
A. Main plot – Nutrient Management													
1. Control (No nutrient)	NM$_0$	25818	25818	25818	60266	63171	61718	34448	37353	35900	1.33	1.44	1.38
2. 100% RDF (20:40:20 NPK kg ha^{-1})	NM$_1$	28344	28344	28344	82151	87565	84858	53807	59221	56514	1.89	2.08	1.98
3. 75% RDF + 2 t FYM ha^{-1}	NM$_2$	31629	31629	31629	80053	83654	81853	48424	52025	50224	1.53	1.64	1.58
4. 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*	NM$_3$	32089	32089	32089	98425	105184	101804	66336	73095	69715	2.06	2.27	2.16
B. Sub plot – Weed Management													
1. Unweeded	WM$_0$	25753	25753	25753	55769	60511	58140	30016	34758	32387	1.16	1.34	1.25
2. Weed free	WM$_1$	39227	39227	39227	98486	103228	100857	59259	64001	61630	1.51	1.63	1.57
3. Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 Hand weeding at 30 DAS	WM$_2$	31142	31142	31142	91737	96445	94091	60595	65303	62949	1.94	2.09	2.01
4. Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS	WM$_3$	24754	24754	24754	78405	83215	80810	53651	58461	56056	2.16	2.36	2.26
5. Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS	WM$_4$	26457	26457	26457	66388	70824	68606	39931	44367	42149	1.50	1.67	1.58

Gross returns were influenced to a high extent due to different nutrient management practices. The highest gross returns (Rs. 98425, 105184 and 101804 ha^{-1}) was found with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM$_3$) followed by NM$_1$ (Rs. 82151, 87565 and 84858 ha^{-1}) and NM$_2$ (Rs. 80053, 83654 and 81853 ha^{-1}), however, the lowest gross returns (Rs. 60266, 63171 and 61718 ha^{-1}) was recorded under control treatment (NM$_0$) during first year, second year and pooled respectively, of experimentation, highest gross returns (Rs. 98486, 103228 and 100857 ha^{-1}) was recorded under weed free treatment (WM$_1$) whereas, unweeded treatment recorded the lowest gross returns of (Rs. 55769, 60511 and 58140 ha^{-1}). Among herbicide treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM$_2$) recorded highest gross returns (Rs. 91737, 96445 and 94091 ha^{-1}) followed by WM$_3$ (Rs. 78405, 83215 and 80810 ha^{-1}) and WM$_4$ (Rs. 66338, 70824 and 68606 ha^{-1}) during first year, second year and pooled respectively, of experimentation.

Net returns were influenced due to different nutrient management practices. The highest net returns (Rs. 66336, 73095 and 69715 ha^{-1}) were recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM$_3$) followed by NM$_1$ (Rs. 53807, 59221 and 56514 ha^{-1}) and NM$_2$ (Rs. 48424, 52025 and 50224 ha^{-1}), however, the lowest net returns (Rs.

34448, 37353 and 35900 ha^{-1}) were recorded under control treatment (NM_0) during first year, second year and pooled respectively, of experimentation, highest net returns (Rs. 60595, 65303 and 62949 ha^{-1}) were recorded under Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) *fb* weed free treatment (Rs. 59259, 64001 and 61630 ha^{-1}), WM_3 (Rs. 53651, 58461 and 56056 ha^{-1}) and WM_4 (Rs. 39931, 44367 and 42149 ha^{-1}), whereas, unweeded plots recorded lowest net returns (Rs. 30016, 34758 and 32387 ha^{-1}) during first year, second year and pooled respectively, of experimentation.

The maximum B:C ratio (2.06, 2.27 and 2.16) was recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (1.89, 2.08 and 1.98) and NM_2 (1.53, 1.64 and 1.58), however, the minimum B:C ratio (1.33, 1.44 and 1.39) was recorded under control treatment (NM_0) during first year, second year and pooled respectively, of experimentation, weed management practices also influenced B: C ratio of pea crop. Maximum B: C ratio (2.16, 2.36 and 2.26) was recorded under Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS (WM_3), whereas, unweeded plots recorded minimum B: C ratio (1.16, 1.34 and 1.25). Among herbicide treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum B: C ratio (1.94, 2.09 and 2.01) followed by WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) and weed free treatment (WM_1) during first year, second year and pooled respectively.

Discussion

Growth of field pea

The data pertaining to the growth characters *viz.*, germination count, crop stand, plant height (cm), number of primary and secondary branches $plant^{-1}$, fresh weight and dry matter accumulation (g $plant^{-1}$) have influenced due to different nutrient management practices have been tabulated in table 1 (a & b). It is evident from the data that all the growth characters of the crop were recorded highest under the treatment NM_3 (75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB)* whereas, the lowest values were associated with control treatment during first year, second year and pooled respectively, of experimentation. It is due to higher availability of the nutrients in concern treatment. Crop growth was rapid in this treatment due to sufficiency of the nutrients available to the crop in association with other inputs *viz.*, moisture, oxygen, solar radiation and space.

Weed management practices also influenced significantly during first year, second year and pooled respectively, of experimentation. Highest values of all the growth parameters were recorded under weed free treatment (WM_1) whereas unweeded treatment recorded lowest values of growth parameters. Among herbicides treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum growth parameters followed by WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) and WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) during first year, second year and pooled respectively, of experimentation. It may be due to controlled density of weeds resulting less or no competition of weeds with crop for inputs concerned. Similar findings were also reported by Rather *et al.,* (2010) [18], Bhat *et al.*, (2013) [4], Uikey *et al.,* (2015) [25], Desai *et al.,* (2016) [6], Pandey (2017) [16], Abera and Abebe (2018) [1], Raja *et al.*, (2022) [17] and Singh *et al.*, (a) (2023) [23].

The data pertaining to root development studies *viz.*, length of main root (cm), number of primary roots $plant^{-1}$ and number of effective nodules $plant^{-1}$ have been tabulated in table 1c. All the root studies of the field pea were recorded highest under the treatment NM_3 (75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB)* whereas, the lowest values were associated with control treatment during first year, second year and pooled respectively, of experimentation. Root studies was rapid in this treatment due to sufficiency of the nutrients available to the crop in association with other inputs *viz.,* nitrogen fixation by nodules, moisture, oxygen, solar radiation and space which resulted in higher values of root studies.

Weed management practices also influenced root studies, highest values of all the root studies were recorded under weed free treatment (WM_1) which resulted in higher values of root studies. Whereas, unweeded treatment recorded lowest values of root studies. Among herbicides treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum values of root studies followed by WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) and WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) during first year, second year and pooled respectively, of experimentation. It may be due to controlled density of weeds resulting less or no competition of weeds with crop for inputs concerned. Similar findings were also reported by Bhat *et al.*, (2013) [4], Uikey *et al.*, (2015) [25], Desai *et al.,* (2016) [6], Pandey *et al.,* (2017) [16], Abera and Abebe (2018) [1], Raja *et al.*, (2022) [17], Singh *et al.*, (a) (2023) and Singh *et al.,* (b) (2023) [23].

Yield of field pea

The yield has been expressed in terms of grain yield (q ha^{-1}), straw yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index (%). The highest grain, straw and biological yield of field pea were recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (100% RDF) and NM_2 (75% RDF + 2 t FYM ha^{-1}), however, the lowest grain, straw and biological yield (q ha^{-1}) were recorded under control treatment (NM_0) during first year, second year and pooled respectively, of experimentation. Treatment NM_3 (75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*) produced 83.34, 87.42 & 85.56% (grain yield), 13.01, 12.25 & 12.61% (straw yield) and 30.11, 31.01 and 30.57% (biological yield) more during first year, second year and as pooled, respectively over control treatment. Weed management practices also influenced the grain, straw and biological yield (q ha^{-1}) of pea crop significantly. Highest grain, straw and biological yield (q ha^{-1}) were recorded under weed free treatment (WM_1) whereas unweeded plots recorded minimum grain, straw and biological yield (q ha^{-1}). Among herbicides treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum grain, straw and biological yield (q ha^{-1}) followed by WM_3 (Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS) and WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) during first year, second year and pooled respectively, of experimentation. Treatment WM_1 recorded an increment of 37.88, 36.35 & 37.10% (grain yield), 18.45, 18.08 & 18.26% (straw yield) and 37.88, 36.35 and 37.10% (biological yield) during first year, second year and pooled, respectively over unweeded treatment.

Yield is the result of estimation of all the yield attributing characters of a crop. Higher yield under concern treatments is due to higher values of yield attributes as well. Controlled weed density allow crop to unhindered growth and development hence higher productivity and quality produce under associated treatments in trends.

The highest harvest index of field pea was recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (100% RDF) and NM_2 (75% RDF + 2 t FYM ha^{-1}), however, the lowest harvest index(%) was recorded under control treatment (NM_0) during both the year of study. Weed management practices also influenced the harvest index of field pea crop significantly. Highest harvest index was recorded under weed free treatment (WM_1) whereas unweeded plots recorded minimum harvest index. Among herbicides treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum harvest index *fb* WM_3 (Imazethapyr @ 25 ml ha^{-1} as *PoE* at 15-20 DAS) and WM_4 (Quizalofop ethyl @ 75 g ha^{-1} as *PoE* at 10-15 DAS) during first year, second year and pooled respectively, of experimentation. Similar results were also reported by Rather *et al.*, (2010) [18], Kumar *et al.*, (2011) [12], Anupama *et al.*, (2012) [2], Bhat *et al.*, (2013) [4], Mishra (2014) [15], Desai *et al.*, (2016) [6], Dhiman (2016) [8], Pandey *et al.*, (2017) [16], Saikia (2018) [20], Gahatraj and Uprety (2019) [10], Ruheentaj (2020) [19], Raja *et al.*, (2022) [17], Singh *et al.*, (a) (2023) [23] and Singh *et al.*, (b) (2023) [23].

Profitability

Economic assessment of treatments within agronomic crop research holds paramount significance in determining their feasibility. In contemporary agriculture, prioritizing maximal profit has superseded the quest for maximum yield. Evaluating diverse treatments hinges primarily on their economic sustainability. This evaluation encompasses cost of cultivation, gross returns, net returns and the benefit-to-cost ratio on a per-hectare basis. Highest cost of cultivation (Rs. 32089, 32089 and 32089 ha^{-1}) was involved with treatment NM_3 (application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*) followed by NM_2 (Rs. 31629, 31629 and 31629) and NM_1 (Rs. 28344, 28344 and 28344 ha^{-1}), however, the lowest cost of cultivation (Rs. 25818, 25818 and 25818 ha^{-1}) was estimated under control treatment (NM_0) during first year, second year and pooled respectively, of experimentation. Weed management practices also influenced cost of cultivation of field pea crop. Highest cost of cultivation (Rs. 39227, 39227 and 39227 ha^{-1}) was calculated under weed free treatment (WM_1) whereas, Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS (WM_3) involved lowest cost of cultivation (Rs. 24754, 24754 and 24754 ha^{-1}). Among herbicide treatments, application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded highest cost of cultivation (Rs. 31142, 31142 and 31142 ha^{-1}) followed by WM_4 (Rs. 26457, 26457 and 26457 ha^{-1}) and WM_0 (Rs. 25753, 25753 and 25753 ha^{-1}) during first year, second year and pooled respectively.

Gross returns were influenced to a high extent due to different nutrient management practices. The highest gross returns (Rs. 98425, 105184 and 101804 ha^{-1}) was found with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (Rs. 82151, 87565 and 84858 ha^{-1}) and NM_2 (Rs. 80053, 83654 and 81853 ha^{-1}), however, the lowest gross returns (Rs. 60266, 63171 and 61718 ha^{-1}) was recorded under control treatment (NM_0) during first year, second year and pooled respectively, of experimentation. Gross returns was also influenced by weed management treatments, highest gross returns (Rs. 98486, 103228 and 100857 ha^{-1}) was recorded under weed free treatment (WM_1) whereas, unweeded treatment recorded the lowest gross returns of (Rs. 55769, 60511 and 58140 ha^{-1}). Among herbicide treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded highest gross returns (Rs. 91737, 96445 and 94091 ha^{-1}) followed by WM_3 (Rs. 78405, 83215 and 80810 ha^{-1}) and WM_4 (Rs. 66338, 70824 and 68606 ha^{-1}) during first year, second year and pooled respectively.

Net returns were influenced due to different nutrient management practices. The highest net returns (Rs. 66336, 73095 and 69715 ha^{-1}) were recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (Rs. 53807, 59221 and 56514 ha^{-1}) and NM_2 (Rs. 48424, 52025 and 50224 ha^{-1}), however, the lowest net returns (Rs. 34448, 37353 and 35900 ha^{-1}) were recorded under control treatment (NM_0) during first year, second year and pooled respectively, of experimentation. Weed management practices also influenced net returns of field pea crop significantly. Highest net returns (Rs. 60595, 65303 and 62949 ha^{-1}) were recorded under Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) *fb* weed free treatment (Rs. 59259, 64001 and 61630 ha^{-1}), WM_3 (Rs. 53651, 58461 and 56056 ha^{-1}) and WM_4 (Rs. 39931, 44367 and 42149 ha^{-1}), whereas, unweeded plots recorded lowest net returns (Rs. 30016, 34758 and 32387 ha^{-1}) during first year, second year and pooled respectively, of experimentation. The maximum B: C ratio (2.06, 2.27 and 2.16) was recorded with application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* (NM_3) followed by NM_1 (1.89, 2.08 and 1.98) and NM_2 (1.53, 1.64 and 1.58), however, the minimum B: C ratio (1.33, 1.44 and 1.39) was recorded under control treatment (NM_0) during first year, second year and pooled respectively, of experimentation. Weed management practices also influenced B: C ratio of pea crop. Maximum B: C ratio (2.16, 2.36 and 2.26) was recorded under Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS (WM_3), whereas, unweeded plots recorded minimum B: C ratio (1.16, 1.34 and 1.25). Among herbicide treatments application of Pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 hand weeding at 30 DAS (WM_2) recorded maximum B: C ratio (1.94, 2.09 and 2.01) followed by WM_4 (Quizalofop ethyl 5% EC @ 75 g *a.i.* ha^{-1} as *PoE* at 10-15 DAS) and weed free treatment (WM_1) during first year, second year and pooled respectively, of experimentation. Similar economic interventions were reported by Varsha *et al.*, (2015) [26], Dhiman (2016) [8], Bhavya and Hiremath (2017) [5], Devi *et al.*, (2018) [7], Gahatraj and Uprety (2019) [10], Sengar *et al.*, (2020) [21], Sharma *et al.*, (2021) [22], Raja *et al.*, (2022) [17], Kumar *et al.*, (2023) [13], Singh *et al.*, (a) (2023) [23] and Singh *et al.*, (b) (2023) [23].

Conclusion

Highest productivity of field pea have been achieved with the application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* with weed control using pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 Hand weeding at 30 DAS and the maximum net returns was fetched when nutrient management was done by application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*, (Rs. 66336, 73095 and 69715 ha^{-1}) and weeds were controlled with pendimethalin 30% EC @ 1.0 kg *a.i.* ha^{-1} as *PE* + 1 Hand weeding at 30 DAS, (Rs. 60595, 65303 and 62949 ha^{-1}), during first year, second year and pooled respectively. But, Maximum B: C ratio was fetched when nutrient management was done by application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB*, (2.06, 2.27 and 2.16) and weeds were controlled by Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS, (2.16, 2.36 and 2.26) during first year, second year and pooled respectively, of experimentation.

Recommendation

Maximum productivity and economic returns from field pea can be achieved with the application of 75% RDF + 2 t FYM ha^{-1} + *Rhizobium* + *PSB* with weed control using Imazethapyr 10% SL @ 25 ml *a.i.* ha^{-1} as *PoE* at 15-20 DAS.

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