RESEARCH ARTICLE Legume Research- An International Journal, Volume 48 Issue 9: 1541-1546 (September 2025)

Response of IWM Strategies on Growth, Nodulation, Productivity and Profitability in Fenugreek (*Trigonella foenum-graecum* L.) under Haryana Conditions

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10.18805/LR-5164

ABSTRACT

Background: This research aims to analyze the effects of IWM strategies on growth, nodulation and nutrient uptake in *Trigonella foenum-graecum* L. under Haryana conditions.

Methods: Field experiments were conducted for two successive years with *Trigonella foenum-graecum* L. sown at Agronomy Research farm (29°10′N, 75°46′E), CCS Haryana Agricultural University, Hisar, Haryana during 2018-19 and 2019-20 to investigate the impact of factors on growth and economics of *Trigonella foenum-graecum* L.

Result: Among the integrated treatments, application of pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} + one hoeing at 3-4 leaf stage recorded maximum nitrogen, phosphorus and potassium uptake by seed and haulm and was found to be at par with weed free check. PRE pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} + one hoeing at 3-4 leaf stage provided highest net returns (Rs. 27,579 ha^{-1}) and highest B: C (2.13) was observed in PRE pendimethalin + imazethapyr (RM) at 1500 g ha^{-1}, respectively. This article aims to document the role of IWM and concludes that coupling pendimethalin and imazethapyr and supplementing them with one hand hoeing will provide effective weed management.

Key words: Economics, Hoeing, Imazethapyr, Nodulation, Nutrient.

INTRODUCTION

Legume is recognized as the most beneficial plant because of having high grain protein contents and ability to fix biological nitrogen. The genus *Trigonella* is one of the largest genera of the tribe *Trifoliate* in the family *Fabaceae* and sub-family *Papilionaceae* (Balodi and Rao, 1991). Fenugreek (*Trigonella foenum-graecum* L.) prevalently known as its vernacular name “Methi” is an important condiment crop grown in northern India during *rabi* season. Fenugreek, a grain legume crop, occupying 169 thousand ha area with an annual output of 252 thousand MT and average productivity of 1.7 MT ha^{-1} (Anonymous, 2021). It is considered to be one of the important pulse crops having a rich source of protein (23 to 24%), macro and micronutrients (Ca, P, K, Fe and Zn), vitamins (niacin, vitamin A, ascorbic acid and inositol), fiber, carbohydrate (Semwal *et al*., 2023).

Crop types and soil properties have greatest influence on the occurrence of weed species in a particular crop (Lugowska *et al*., 2016). Some pre-emergence (PRE) and post-emergence (POE) herbicides efficacy have been evaluated against weed flora in legumes. Imazethapyr applied as PPI, PRE and POE controls monocot and dicot weeds and had a strong residual life (Punia *et al*., 2011). Herbicides applied pre-emergence (PRE) or early post-emergence (POE) may not always provide season long weed control necessitating the use of integrated techniques for effective control. Therefore, a better and more suitable weed control method is needed for season long effective control of weeds in fenugreek with no adverse effect on succeeding sensitive crops. Keeping these points in view, it was considered to carry out field experiment on the efficacy of imazethapyr applied alone and its ready mixture with pendimethalin or imazamox in fenugreek crop. A recent decline in commodity prices and increasing herbicide costs to manage herbicide resistant HR weeds has spurred research efforts to build a strong rationale for developing ecologically based integrated weed management (IWM) strategies in the Indo-gangetic Plains. This article aims to document the role of IWM that will ultimately aid in achieving sustainable weed management goals and preserving the

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How to cite this article: Ahlawat, I., Todarmal, Bhardwaj, S., Bhardwaj, K.K., Dahiya, G., Abhishek and Rana, A. (2025). Response of IWM Strategies on Growth, Nodulation, Productivity and Profitability in Fenugreek (*Trigonella foenum-graecum* L.) under Haryana Conditions. *Legume Research.* **48(9):** 1541-1546. doi: 10.18805/LR-5164.

Submitted: 02-05-2023 **Accepted:** 12-10-2023 **Online:** 27-10-2023

natural resources. Nutrients are very much essential for growth and development of fenugreek crop and their deficiency will decrease the crop yield. Therefore, it is imperative to know the uptake of nutrients by crop. Hence, the present study was undertaken with the aim to investigate the impacts of integrated weed management techniques on the growth, nodulation and nutrient uptake of fenugreek crop.

MATERIALS AND METHODS

Field experiments were conducted during the winter season of 2018-19 and 2019-20 at Agronomy Research Farm (29° 10′N, 75°46′E), CCS Haryana Agricultural University, Haryana. Fenugreek (Variety: HM-51) was sown on 22 November, 2018 and 19 November, 2019 during 2018-19 and 2019-20, respectively and the plot size was 6 by 6 m with a row spacing of 20 cm and seeding rate 25 kg per hectare. The soil at the experimental site was determined as sandy loam in texture, slightly alkaline in reaction (pH 7.8) and normal in electrical conductivity (0.28 dS m^{-1}). Field trials were set up with three replications in a randomised complete block design using six row m^2 plots with fifteen treatments. To ensure a homogenous plant population, excess plants were thinned out. The crop received 28.6 and 32.4 mm of rainfall in the crop growing season during both seasons, respectively. The soil of experimental field was sandy-loam at Hisar (58% sand, 32% silt and 10% clay). It was medium in organic carbon (0.51%), low in nitrogen (181 kg ha^{-1}), medium in phosphorus (17 kg ha^{-1}) and high in potassium (285 kg ha^{-1}) at experimental area. Fields were fertilised with 20 and 40 kg ha^{-1} of nitrogen and phosphorous, respectively through DAP before sowing during both seasons. The experiment was conducted in a field heavily infested with broad-leaved weeds.

The herbicide treatments evaluated consisted of fifteen treatments in total. Weed free and weedy treatments were included for comparison of efficacy. Experimental treatments comprised weedy check, weed free, PRE imazethapyr at 80 g ha^{-1}, PRE imazethapyr + imazamox (RM) at 70 g ha^{-1}, PRE pendimethalin at 1000 g ha^{-1}, PRE pendimethalin + imazethapyr (RM) at 1000 g ha^{-1}, PRE pendimethalin + imazethapyr (RM) at 1250 g ha^{-1}, PRE pendimethalin + imazethapyr (RM) at 1500 g ha^{-1}, POE imazethapyr at 80 g ha^{-1} at 3-4 leaf stage, POE imazethapyr + imazamox (RM) at 70 g ha^{-1} at 3-4 leaf stage, PRE imazethapyr at 80 g ha^{-1} + one hoeing at 3-4 leaf stage, PRE imazethapyr + imazamox (RM) at 70 g ha^{-1} + one hoeing at 3-4 leaf stage, PRE pendimethalin at 1000 g ha^{-1} + one hoeing at 3-4 leaf stage, PRE pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} + one hoeing at 3-4 leaf stage and two hoeing at 30 and 60 DAS. Plant protection measures and irrigations were followed as per recommendation. The pre-emergence herbicide was sprayed immediately after sowing on wet soil and post-emergence herbicides at 46 DAS as per treatment with knapsack sprayer.

Randomly five plants were selected from each plot and regular observations of crop and weed parameters were recorded from 30 DAS upto harvest. Nodule parameters *viz.* number and dry weight of nodules/plant were observed both at 40 and 60 DAS. Chlorophyll A and B content was recorded at 75 DAS (Kapoor *et al.,* 2017). To estimate the N, P and K content, samples were collected at harvest for crop. Nutrient uptake by seed and haulm was calculated on the basis of dry matter yield with the nutrient content and expressed in kg ha^{-1}. Estimation of nitrogen was done by colorimetric method using Nessler's reagent to develop colour. Phosphorus content was determined by Vanadomolybdo phosphate yellow colour method (Jackson, 1967) and potassium by Flame photometric method.

The data were subjected to analysis of variance and significant differences among treatments were tested. Differences among treatment means were determined using ANOVA and when the F-test was significant, means were compared with LSD test at 5% level of significance.

RESULTS AND DISCUSSION

Broad-leaf weeds were present at comparatively higher densities and consisted mainly of *Melilotus indica* (7.7%), *Anagallis arvensis* (23.5%), *Rumex dentatus* (14.0%), *Lathyrus aphaca* (11.8%), *Medicago denticulata* (21.6%) and *Coronopus didymus* (7.7%) and among grassy weed *Phalaris minor* (13.7%) at 45 DAS.

Days taken to obtain 50% flowering (Table 1) were significantly higher under Pendimethalin at 1000 g ha^{-1} PRE and imazethapyr at 80 g ha^{-1} applied at 3-4 leaf stage as well as PRE and these were statistically at par with weedy check. The data revealed that Pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} + one hoeing at 3-4 leaf stage recorded minimum days to maturity excluding weed free treatment. Nodule parameters *viz.* number and dry weight of nodules/plant were observed both at 40 and 60 DAS (Table 1). All the weed-control measures had significantly positive impact on number and dry weight of nodules of fenugreek as compared to weedy check at all the growth stages. Number of nodules/plant were maximum under pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} + one hoeing at 3-4 leaf stage and it was statistically at par with PRE pendimethalin + imazethapyr (RM) applied at 1000, 1250 and 1500 g ha^{-1}. Pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} + one hoeing at 3-4 leaf stage application recorded significantly higher dry weight of nodules amongst all the chemical treatments which was at par with weed free treatment. In case of efficient weed control treatments, better weed management provided professed root development and bacterial colonies, which ultimately resulted in more nodulation in crop especially in herbicidal treatments with PRE Pendimethalin + imazethapyr (Dubey *et al*., 2018). Pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} + one hoeing at 3-4 leaf stage depicted higher nodular count owing to infestation of Rhizobium in the growing roots as compared to more crop weed competition in unweeded check (Nirala *et al*., 2016; Sharma *et al*., 2017). Amongst herbicide treated plots, both chlorophyll A and B were significantly higher in

Table 1: Effect of herbicidal treatments on yield attributes of fenugreek (2018-19 and 2019-20).

Treatment	Dose (g ha^{-1})	Time of application	Days to 50% flowering	Days to maturity	No. of nodules/plant		Dry weight of nodules (mg/plant)		Chlorophyll content (mg/g fresh weight)	
					40 DAS	60 DAS	40 DAS	60 DAS	A	B
Imazethapyr	80	PRE	52.2	116.2	5.4	11.6	8.7	24.2	1.31	0.77
Imazethapyr + one hoeing	80	PRE and 3-4 leaf stage	49.4	112.2	5.5	15.8	8.9	31.9	1.89	1.48
Imazethapyr	80	3-4 leaf stage	52.3	116.7	4.3	11.1	7.8	23.9	1.25	0.73
Imazethapyr + imazamox (RM)	70	PRE	51.9	115.1	5.9	12.3	9.4	25.2	1.43	0.85
Imazethapyr + imazamox (RM)	70	3-4 leaf stage	52.0	115.8	4.3	11.9	7.9	24.7	1.38	0.82
Imazethapyr + imazamox (RM) + one hoeing	70	PRE and 3-4 leaf stage	48.8	111.9	6.1	15.6	9.6	32.6	2.13	1.59
Pendimethalin	1000	PRE	52.3	116.8	5.1	10.9	8.4	23.3	1.20	0.69
Pendimethalin + one hoeing	1000	PRE and 3-4 leaf stage	49.9	112.8	5.1	15.1	8.5	31.4	1.75	1.34
Pendimethalin + imazethapyr (RM)	1000	PRE	51.7	114.1	6.6	13.3	10.2	27.7	1.56	0.97
Pendimethalin + imazethapyr (RM)	1250	PRE	51.2	113.7	6.9	13.9	10.7	29.2	1.61	1.06
Pendimethalin + imazethapyr (RM)	1500	PRE	50.4	113.3	7.3	14.3	12.1	30.1	1.69	1.15
Pendimethalin + imazethapyr (RM) + one hoeing	1500	PRE and 3-4 leaf stage	48.2	111.2	7.4	16.1	12.3	33.6	2.25	1.62
Weedy free	-	-	47.3	109.8	8.1	17.1	12.9	35.3	2.49	1.73
Weedy check	-	-	54.6	117.4	4.1	9.2	7.4	19.3	1.12	0.65
Two hoeing	-	30 and 60 DAS	47.9	110.4	7.8	16.7	12.6	34.5	2.32	1.68
LSD (P=0.05)	-	-	2.4	3.0	0.8	1.7	0.9	3.9	0.4	0.1

pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} + one hoeing at 3-4 leaf stage which was at par with imazethapyr + imazamox (RM) at 70 g ha^{-1} + one hoeing at 3-4 leaf stage in case of chlorophyll A. The increase in chlorophyll content of the crop under weed control treatment with PRE Pendimethalin + imazethapyr at 1500 g ha^{-1} can be clearly attributed to the reduction in interference of the weeds as evident from the higher weed control efficiency which ultimately favoured better growth environment for the crop (Sharma *et al*., 2017). Thus, under lesser crop weed competition, adequate availability of light, temperature and space along with moisture and nutrients, improved physiological and morphological characters of plant as well as photosynthesis with greater rate ultimately leads to more chlorophyll content in plants (Duncan, 1971).

Nutrient content in seed was recorded and significantly the lowest content of nitrogen, phosphorus and potassium by seed was noted under unweeded control (Fig 1) and maximum was observed under pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} + one hoeing at 3-4 leaf stage. Significant increase in total N, P and K content in haulm was recorded due to all weed management practices over weedy check (Fig 2). The highest nutrient content in haulm was recorded under weed free up to harvest. Similarly, all the weed control treatments significantly increased N, P and K uptake by seed and straw of fenugreek over weedy check (Table 2). Weed free treatment resulted in significantly highest total uptake of N (65.2 kg/ha), P (9.8 kg/ha) and K (12.7 kg/ha) by the crop compared to weedy check (21.2, 2.6 and 3.7 kg/ha), respectively. Among the integrated treatments, application of pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} + one hoeing at 3-4 leaf stage recorded maximum nitrogen, phosphorus and potassium uptake by seed and haulm and was found to be at par with weed free check. This might be due to better development of crop resulting from lesser crop weed competition, further, the higher content and higher dry matter accumulation by crop under these treatments boosted the nutrient uptake. Lower nitrogen, phosphorous and potassium uptake was recorded in unweeded control due to poor root growth and establishment as a consequence of severe crop-weed competition. Significantly lower value of growth parameters *viz*. number and dry weight of nodules,

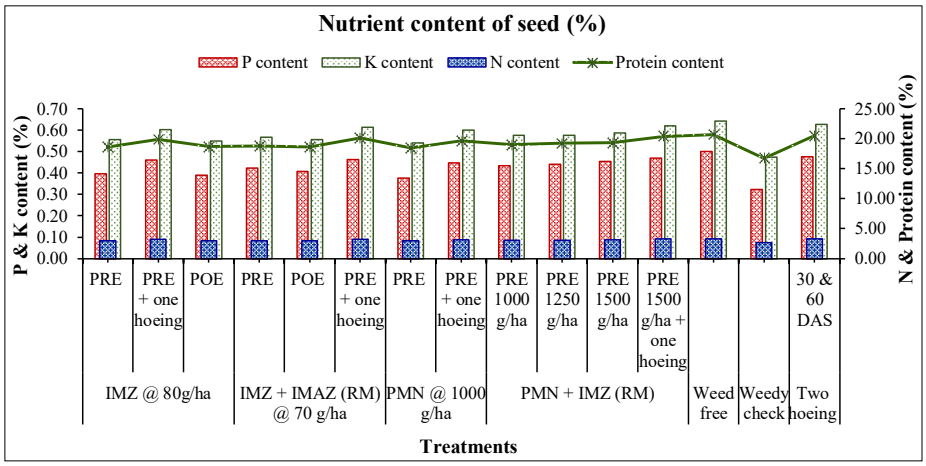

Fig 1: Effect of herbicidal treatments on nutrient and protein content of seed (%) in fenugreek (2018-19 and 2019-20) (p= 0.05).

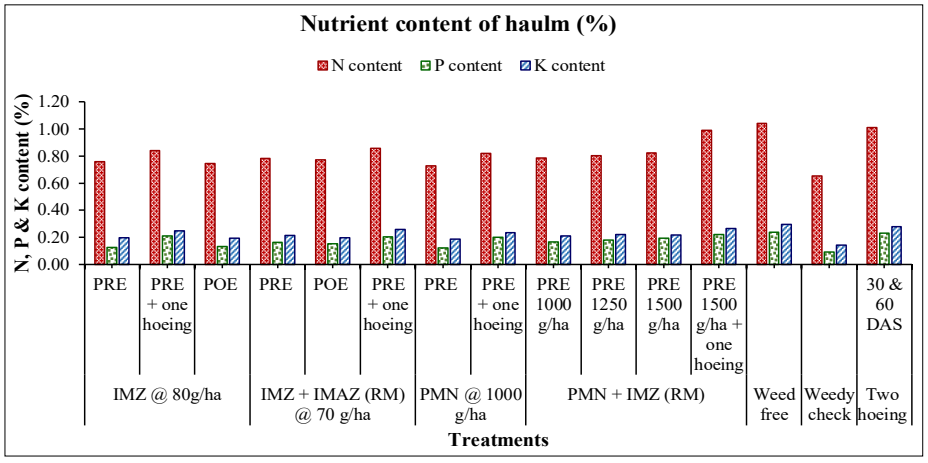

Fig 2: Effect of herbicidal treatments on nutrient of haulm (%) in fenugreek (2018-19 and 2019-20) (p= 0.05).

Table 2: Effect of herbicidal treatments on nutrient uptake of seed in fenugreek (2018-19 and 2019-20).

Treatment	Dose (g ha^{-1})	Time of application	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})		Protein yield (kg ha^{-1})
			Seed	Haulm	Seed	Haulm	Seed	Haulm	
Imazethapyr	80	PRE	38.6	32.5	5.1	5.4	7.2	8.4	242
Imazethapyr + one hoeing	80	PRE and 3-4 leaf stage	58.0	40.0	8.4	10.0	11.0	11.7	363
Imazethapyr	80	3-4 leaf stage	37.5	31.3	4.9	5.6	6.9	8.1	234
Imazethapyr + imazamox (RM)	70	PRE	42.3	34.5	5.9	7.2	8.0	9.4	264
Imazethapyr + imazamox (RM)	70	3-4 leaf stage	40.8	33.6	5.6	6.7	7.6	8.5	255
Imazethapyr + imazamox (RM) + one hoeing	70	PRE and 3-4 leaf stage	59.5	40.9	8.6	9.7	11.3	12.2	372
Pendimethalin	1000	PRE	35.5	29.6	4.5	5.0	6.5	7.6	222
Pendimethalin + one hoeing	1000	PRE and 3-4 leaf stage	52.5	37.5	7.4	9.2	10.0	10.7	328
Pendimethalin + imazethapyr (RM)	1000	PRE	44.1	34.6	6.3	7.3	8.4	9.2	276
Pendimethalin + imazethapyr (RM)	1250	PRE	45.9	35.4	6.6	7.9	8.6	9.7	287
Pendimethalin + imazethapyr (RM)	1500	PRE	48.0	36.8	7.0	8.6	9.1	9.7	300
Pendimethalin + imazethapyr (RM) + one hoeing	1500	PRE and 3-4 leaf stage	62.2	47.5	9.0	10.6	11.8	12.8	389
Weedy free	-	-	65.2	50.7	9.8	11.5	12.7	14.5	407
Weedy check	-	-	21.2	21.5	2.6	3.0	3.7	4.7	133
Two hoeing	-	30 and 60 DAS	63.4	48.9	9.2	11.1	12.1	13.6	396
LSD (P=0.05)	-	-	8.0	6.6	1.0	0.9	1.7	1.6	13

Table 3: Effect of herbicidal treatments on yield and economics of fenugreek (pooled mean of 2018-19 and 2019-20).

Treatment	Dose (g ha^{-1})	Time of application	Seed yield	Cost of cultivation	Net returns	Additional returns over control	B-C ratio
Imazethapyr	80	PRE	1297	21145	17045	12656	1.80
Imazethapyr + one hoeing	80	PRE and 3-4 leaf stage	1825	29545	24253	19864	1.82
Imazethapyr	80	3-4 leaf stage	1253	21145	15763	11374	1.74
Imazethapyr + imazamox (RM)	70	PRE	1404	21590	19771	15382	1.92
Imazethapyr + imazamox (RM)	70	3-4 leaf stage	1369	21590	18977	14588	1.86
Imazethapyr + imazamox (RM) + one hoeing	70	PRE and 3-4 leaf stage	1846	29990	24425	20036	1.81
Pendimethalin	1000	PRE	1199	20951	14365	9976	1.68
Pendimethalin + one hoeing	1000	PRE and 3-4 leaf stage	1666	29351	19756	15367	1.68
Pendimethalin + imazethapyr (RM)	1000	PRE	1451	21660	21089	16700	1.97
Pendimethalin + imazethapyr (RM)	1250	PRE	1490	22129	21770	17381	1.98
Pendimethalin + imazethapyr (RM)	1500	PRE	1550	22597	23073	18684	2.02
Pendimethalin + imazethapyr (RM) + one hoeing	1500	PRE and 3-4 leaf stage	1909	30997	25264	20875	1.81
Weedy free	-	-	1967	44145	13825	9436	1.31
Weedy check	-	-	792	18945	4389	0	1.23
Two hoeing	-	30 and 60 DAS	1926	35745	21002	16613	1.59

seed yield were recorded in weedy check treatment. This might be due to severe competition by weeds for resources, which made the crop plant inefficient to take up more moisture, nutrients and ultimately growth was adversely affected due to less supply of carbohydrates.

The monetary returns were found to be significantly influenced by different weed control treatments (Table 3). The maximum net returns of Rs. 25264 /ha and additional returns over control Rs. 20875 were obtained with pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} as pre-emergence supplemented with one hoeing at 3-4 leaf stage. Among all the weed control treatments, maximum B-C ratio (2.02) was recorded with treatment pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} as pre-emergence. All the weed management strategies were almost equally important in controlling weeds and improving the crop yield. Weed free treatment was superior most with respect to growth parameters, seed yield (44,145 kg ha^{-1}) and quality. The next best treatment with respect to net returns (Rs. 25264/ha) and B:C ratio (2.02) was pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} as pre-emergence with one hand hoeing at 3-4 leaf stage and PRE pendimethalin + imazethapyr (RM) at 1500 g ha^{-1}, respectively. So, Pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} + one hoeing at 3-4 leaf stage was observed to be the best treatment in terms of yield, nodules, chlorophyll content as well as in monetary terms.

CONCLUSION

The findings of the present study provide herbicide options for the management of predominant weed flora in fenugreek. Research study indicate that alone PE or PoE herbicide treatments are not effective against effective weed management in this legume crop. The farmers can adopt this strategy to tackle the problem of poor efficacy of herbicides in particularly in north-western Indo- Gangetic Plains of India. However, growers and land managers will face increasing pressure to reduce overall pesticide use in food and feed production systems. There are myriad research and development needs for growers and land managers to successfully transition to a limited herbicide world. The metric for successful integrated weed management is lowest weed seed banks as possible concurrent with reduced herbicide use. In area there is paucity of labour, it is advisable to apply pendimethalin + imazethapyr (RM) at 1500 g ha^{-1} as pre-emergence supplemented with one hoeing at 3-4 leaf stage under Haryana conditions.

Conflict of interest

All authors declared that there is no conflict of interest.

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