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Study on Effect of Neem-based Agro-forestry System on Different Leguminous Crops and its Impact on Nitrogen Availability in Soil and Nodulation

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ABSTRACT

Neem plantations, along with the under-storey crops, protect both the soil and the environment and also help in increasing the socio-economic level of the rural people. The crop yields are often limited by nitrogen availability. This limitation can be overcome by intercropping with legumes in the agro-forestry systems. The present study focused on the effect of different legumes on the availability of nitrogen in a neem-based agroforestry system at the farm of RLBCAU, Jhansi, UP. Seven legumes viz., favabean (or fababean), lathyrus, lentil, green pea (garden pea), white pea (field pea), fenugreek and chickpea were studied for parameters viz., number of nodules, size of nodules, number of branches, colour/position of nodules, plant height, soil available nitrogen, soil pH and soil EC. There was a significant increase in the available N of soil after harvesting of the legumes compared to the initial stage. The pH had significant variation with differing nitrogen levels in the soil, thus it had a correlation. Soil EC was not found to be having any significant effect on the nitrogen content in the soil. In conclusion, all leguminous crops improved nitrogen content in the soil and the maximum increase was in the case of lathyrus, followed by chickpea and field pea.

Key words: Legumes, soil available nitrogen, soil health, fertility, agro-forestry

INTRODUCTION

Nitrogen is a vital element essential for the growth and development of plants, making it a cornerstone of agricultural productivity (Ribeiro-Barros *et al*., 2018). However, the availability of nitrogen for crops poses a significant challenge to the sustainability of agricultural systems, the economy and the global food supply. Synthetic fertilizers, while providing nitrogen to crops, also bring about severe environmental concerns.

Unlike chemical nitrogen fixation through fertilizers, biological nitrogen fixation offers a sustainable and eco-friendly alternative (Pankievicz *et al*., 2019). Research indicates that biological nitrogen fixation in legumes, the third-largest family of flowering plants globally, not only replenishes soil fertility but also enhances productivity without harming the environment.

Legumes, ranging from herbs to trees, thrive in diverse climatic conditions, making them crucial components of agricultural systems worldwide (Ribeiro-Barros *et al*., 2018). These plants play a vital role in poverty alleviation efforts, as they promote soil fertility through the action of microbes, influencing biological, chemical, and physical aspects (Stagnari *et al*., 2017; Nanganoa *et al*., 2019; Vasconcelos *et al*., 2020).

Furthermore, the total nitrogen fixation in the world, calculated to be approximately 1.75×10^{11} kg, has a significant contribution from symbiotic nitrogen fixation in legumes, fixing about 8.0×10^{10} kg on average per hectare annually (Shah *et al*., 2021). This natural nitrogen fixation process not only reduces dependence on industrially fixed nitrogen fertilizers (about 8.8×10^{10} kg) but also aids in nutrient transfer to nearby and succeeding crop plants, impacting agricultural productivity (Islam and Adjesiwor, 2017).

Understanding the transfer of biologically fixed nitrogen, including the role of legume nodules and roots, further enhances our grasp of this crucial process. Additionally, the transfer of nutrients to non-legume companion crops within the cropping system and growing season is influenced by various factors, such as legume species, plant component amounts, crop maturity and plant growth vigour (Thilakarathna *et al.*, 2016). Notably, legumes not only contribute to soil fertility but also break disease and pest cycles, benefiting overall crop health (Kebede, 2020).

MATERIALS AND METHODS

The study was carried out as neem-based agro-forestry system at research farm of RLBCAU, Jhansi. Seven legumes viz., favabean (or fababean), lathyrus, lentil, green pea (garden pea), white pea (field pea), fenugreek and chickpea were studied for parameters viz., number of nodules, size of nodules, number of branches, colour/position of nodules, plant height, soil available nitrogen, soil pH and soil EC. Field pea has coloured flowers (*Pisum sativum* var. *arvense* L.) and garden pea has white flowers (*Pisum sativum* var. *Hortense* L). These two cultivars are two types of cultivated peas, the earlier commonly grown as a cover crop, or, in more arid regions, for its smooth dried seeds used as food or feed crops and the latter is more commonly grown for fresh market use. Garden peas contain higher sugar and lower starch contents than field peas and have wrinkled mature seeds.

The experiment was laid out in randomized block design and soil samples were collected before sowing of the seven legumes in the study area at two depths (0-15 and 15-30 cm) in three replications. The samples were air-dried for few days and sieved using a 2 mm sieve into fine particles. At the time of flowering and just before harvesting, number of nodules, size of nodules, plant height, number of branches were recorded in every leguminous system in three replications. After the harvesting of the legumes, soil samples were collected from the seven blocks in three replications each at two depths (0-15 and 15-30 cm).

Soil pH and EC were analyzed following 1:2 solution in distilled water. The initial and after harvesting samples were analyzed for available nitrogen (Av N) in the soil following alkaline potassium permanganate method.

Statistical analysis was done for the comparison and correlation of different parameters using Duncan Multiple Range Test (DMRT). Soil available N, pH and EC were compared between initial and harvesting samples. Correlation between pH and available N was statistically analyzed. Comparison between plant height and number of branches with available N was analyzed. Similarly, comparison between number of nodules and size of nodules with available N was analyzed. Overall study was done for screening out the best legume among all the seven legumes in the neem-based agro-forestry system.

RESULTS AND DISCUSSION

At the flowering stage, the colour of nodules was mostly pink, brown or white and sometimes green. The position of nodules was found to be both on the main roots and lateral roots of the legumes. The number of nodules was recorded in the range of 2.67 to 39.00 and the maximum was found to be 39.00 in fava bean which was followed by 15.00 in field pea and the minimum 2.67 in chick pea. In case of the size of nodules, the range of sizes was recorded in the range of 1.00 to 3.00 mm and the maximum size was found to be 3.00 mm in fava bean and it was followed by 2.67 mm in garden pea and the minimum size was recorded to be 1.00 mm in chick pea (Table 1). At the harvesting time, nodules were absent in most of the legumes and the number of nodules in fava bean and lathyrus was found to be 45.33 and 5.00, respectively. The size of these nodules was recorded to be 4.00 and 7.00 mm, respectively (Table 2).

At the time of flowering, the plant height was recorded to be in the range of 26.00 to 39.67 cm and the maximum height was found to be 39.67 cm in field pea, it was followed by 32.00 cm in both lathyrus and garden pea and the minimum was recorded to be 26.00 cm in chickpea (Table 1). At the harvesting time, the plant height was recorded to be in the range of 41.33 to 81.67 cm and the maximum was recorded 81.67 cm in field pea, followed by 72.67 cm in lathyrus and the least was recorded to be 41.33 cm in chickpea (Table 2).

On the basis of directions and distances of tree planting, plant height of pigeon pea [*Cajanus cajan* (L.) Millsp.] was recorded to be in the range of 52.00 to 94.00 cm at 90 days after sowing (DAS). At harvesting time, the plant height was recorded to be 67.5 to 30.80 cm (Honnayya *et al*, 2020). At the time of flowering,

Table 1. Status of nodules in different legumes at flowering

Treatment	No. of nodules	Size of nodules (mm)	Plant height (cm)	No. of branches
Fava bean	39.00±11.7^{a}	3.00±1.00^{a}	30.67±7.09^{ab}	2.33±0.58^{c}
Lathyrus	4.67±0.58^{cd}	2.33±1.53^{ab}	32.00±10.82^{ab}	3.33±1.15^{bc}
Lentil	9.00±4.58^{bcd}	1.67±0.58^{ab}	27.00±4.58^{ab}	5.00±1.00^{a}
Garden pea	15.00±2^{b}	1.67±0.58^{ab}	39.67±4.93^{a}	2.67±0.58^{c}
Field pea	13.67±4.51^{bc}	2.67±1.15^{ab}	32.00±8.72^{ab}	2.33±0.58^{c}
Fenugreek	9.33±4.16^{bcd}	2.00±1.00^{ab}	28.33±3.51^{ab}	4.33±0.58^{ab}
Chickpea	2.67±0.58^{d}	1.00±0.00^{b}	26.00±2.00^{b}	2.67±0.58^{c}

Different superscripts are significantly different.

Table 2. Status of nodules in different legumes at harvesting

Treatment	No. of nodules	Size of nodules (mm)	Plant height (cm)	No. of branches
Fava bean	45.33	4.00	44.67±2.52^{cd}	2.67±1.53^{b}
Lathyrus	5.00	7.00	72.67±4.04^{b}	3.67±0.58^{ab}
Lentil	-	-	44.67±2.52^{cd}	4.00±1.00^{ab}
Garden pea	-	-	81.67±7.64^{a}	3.00±1.00^{ab}
Field pea	-	-	49.00±4.58^{cd}	5.00±1.00^{a}
Fenugreek	-	-	51.33±4.04^{c}	3.67±1.15^{ab}
Chickpea	-	-	41.33±3.06^{d}	5.00±1.00^{a}

Different superscripts are significantly different.

the number of branches was recorded to be in the range of 2.33 to 5.00 and the maximum branches were found to be 5.00 in lentil, followed by 4.33 in fenugreek and the minimum 2.33 in both fava bean and garden pea (Table 1).

At the time of harvesting, number of branches was recorded to be in the range of 2.67 to 5.00 and the maximum was found in chickpea, followed by 4.00 in lentil and the minimum to be 2.67 in fava bean (Table 2). On the basis of directions and distances of tree planting, number of branches of pigeon pea [*Cajanus cajan* (L.) Millsp.] was recorded to be in the range of 3.0 to 6.2 at 90 DAS. At harvesting time, the numbers of branches were recorded to be 5.1 to 9.3 (Honnayya and Doddabasawa, 2020).

The results of soil analysis showed that the pH was recorded in the range of 7.85 to 8.57. The maximum pH was recorded in the garden pea at 0-15 cm depth of soil. Fenugreek (0-15 cm) and garden pea (15-30 cm) showed similar pH of 8.56 and 8.55, respectively. The least pH was recorded as 7.85 in chickpea at 15-30 cm (Table 3).

Fava bean (0-15 cm), white pea (0-15 cm) and fenugreek (0-15 cm) had significant increase in pH after harvesting, while the increase in pH of fava bean (0-15 cm), lentil (0-15 cm), green pea (0-15 cm), green pea (0-15 cm), white pea (15-30 cm), fenugreek (15-30 cm) was insignificant after harvesting. Lathyrus (0-15 cm), chickpea (0-15 cm) and chickpea (15-30 cm) had significant decrease in pH after harvesting, while the decrease in pH was insignificant in case of lathyrus (15-30 cm) and lentil (15-30 cm).

In case of EC, the range was recorded to be 0.055 to 0.101 dS/m and the maximum was recorded to be 0.101 dS/m in field pea (15-30 cm), followed by 0.095 dS/m in lathyrus (0-15 cm) and the minimum was recorded as 0.055 dS/m in lentil (15-30 cm). Based on initial and harvesting sampling, EC decreased but there was no significant decrease after harvesting (Table 3).

The available N was analyzed and recorded to be in the range of 189.83 to 278.48 kg/ha and the maximum was found in lathyrus at 0-15 cm followed by 271.79 kg/ha in chickpea (0-15 cm) and the minimum was recorded to be 189.83 kg/ha in lentil (0-15 cm). There was significant increase in the available N in almost all cases compared to 137.98 kg/ha (0-15 cm) and 133.80 kg/ha (15-30 cm) of available

Table 3. Status of soil before and after harvesting

Treatment (cm)	pH	EC (dS/m)	Av N (kg/ha)
Initial sample (0-15)	8.12±0.04	0.106±0.04	137.98±12.54
Initial sample (15-30)	8.20±0.20	0.114±0.06	133.80±7.24
Fava bean (0-15)	8.25±0.03^{bc}	0.080±0.03^{abc}	209.07±46.37^{c}
Fava bean (15-30)	8.28±0.04^{b}	0.059±0.00^{bc}	240.43±12.05^{abc}
Lathyrus (0-15)	7.99±0.04^{cde}	0.095±0.01^{ab}	278.48±15.67^{a}
Lathyrus (15-30)	7.95±0.04^{de}	0.074±0.01^{abc}	192.34±56.52^{c}
Lentil (0-15)	8.14±0.14^{bcd}	0.072±0.02^{abc}	189.83±27.63^{c}
Lentil (15-30)	8.07±0.15^{bcde}	0.055±0.01^{c}	218.68±25.13^{bc}
Garden pea (0-15)	8.16±0.16^{bcd}	0.092±0.03^{abc}	234.57±25.74^{abc}
Garden pea (15-30)	8.35±0.17^{ab}	0.101±0.02^{a}	222.87±4.41^{bc}
Field pea (0-15)	8.57±0.12^{a}	0.078±0.01^{abc}	243.77±10.82^{abc}
Field pea (15-30)	8.55±0.19^{a}	0.064±0.00^{abc}	204.05±29.75^{c}
Fenugreek (0-15)	8.56±0.16^{a}	0.090±0.04^{abc}	217.01±11.15^{bc}
Fenugreek (15-30)	8.27±0.36^{b}	0.070±0.01^{abc}	194.85±31.37^{c}
Chickpea (0-15)	7.92±0.04^{de}	0.060±0.01^{bc}	271.79±14.48^{ab}
Chickpea (15-30)	7.85±0.03^{e}	0.060±0.02^{bc}	194.85±31.37^{c}

Different superscripts are significantly different.

N in initial samples. Only in case of lathyrus (15 to 30 cm), there was no significant increase in available N after harvesting (Fig. 1).

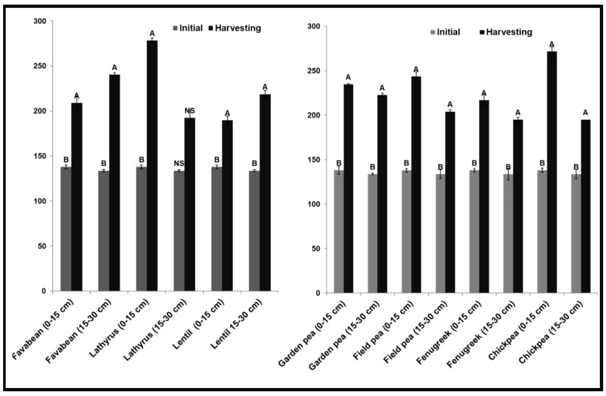

Fig. 1. Soil available nitrogen comparison with initial and harvesting sampling.

The correlation between pH and available N showed significant positive effect in case of lathyrus and chickpea, while in fava bean and garden pea they had insignificant positive effect. In case of field pea, it showed significant negative effect, while the negative effect of lentil and fenugreek was insignificant (Fig. 2). The comparison between plant height and number of branches with available N showed that the plant height and available N had significant correlation with some exceptions as in case of chickpea and fenugreek. Number of branches had no significant correlation with the available N. Similarly, the number of nodules and size of nodules with available N showed that the number of nodules had significant correlation with some exceptions like in case of chickpea and lathyrus. Size of nodules had no significant correlation with the available N (Fig. 3).

CONCLUSION

The study revealed that soil properties were significantly influenced by different legumes under the neem trees. There was a significant increase in available N in the soil after harvesting of the legumes compared to the initial stage. The pH had significant variation with differing nitrogen levels in the soil, thus it had a correlation. Soil EC was not found having any significant effect on the nitrogen content in the soil. The pH and available N were found to have some relationship, and this relationship varied in different legumes. Thus, with a change in pH, the availability of nitrogen differed. Plant height and the number of nodules also had a positive correlation with available nitrogen. Initially, available N was recorded lower and, after harvesting, significant differences were evident in each leguminous system. The maximum amount of available N was recorded in the case of lathyrus at a soil depth of 0-15 cm i.e. 278.48 kg/ha, which was followed by chickpea and field pea. A

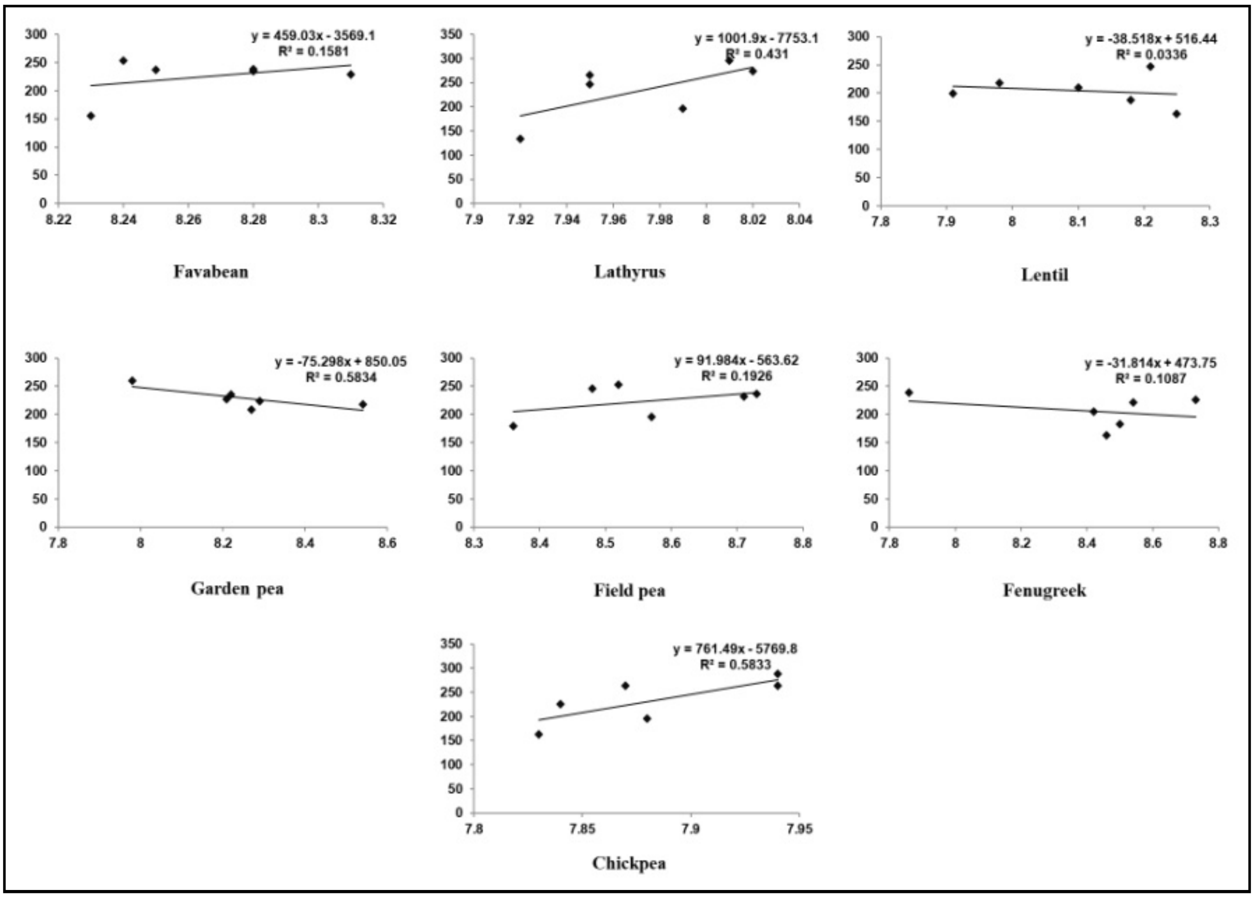

Fig. 2. Correlation between pH and Av. N.

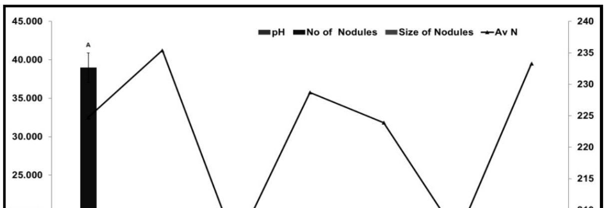

Fig. 3. Comparison between number of nodules and size of nodules with Av. N.

minimum was recorded in the case of lentil at a soil depth of 15-30 cm. Nodulation was found to be directly correlated with increasing available N in the cases of fava bean, garden pea, field pea and fenugreek, though no correlation was found in the case of chickpea. Finally, it was found out that lathyrus, followed by chickpea and field pea, improved soil available nitrogen in the neem-based agro-forestry system.

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REFERENCES

Honnayya, B. M. C. and Doddabasawa. (2020). Productivity of pigeonpea [*Cajanus cajan* (L.) Millsp.] in neem (*Azadirachta indica* A. Juss.)-based agroforestry system on Alfisols in semi-arid tropics. *Agrofor. Syst.* **94**: 1879-1889.

Islam, M. A. and Adjesiwor, A. T. (2017). *Nitrogen Fixation and Transfer in Agricultural Production Systems. Nitrogen Agric. Updates,* Amanullah and Shah Fahad (eds.). Intech Open. pp. 95.

Kebede, E. (2020). Grain legumes production and productivity in Ethiopian smallholder agricultural system, contribution to livelihoods and the way forward. *Cogent*

Food Agric. **6.** *do1: 10.1080/23311932.2020. 1722353.*

Nanganoa, L. T., Njukeng, J. N., Ngosong, C., Atache, S. K. E., Yinda, G. S., Ebonlo, J. N., Ngong, J. N. and Ngome, F. A. (2019). Short-term benefits of grain legume fallow systems on soil fertility and farmers livelihood in the humid forest zone of Cameroon. *Int. J. Sustain. Agric. Res.* **6**: 213-223.

Pankievicz, V., Irving, T. B., Maia, L. G. and Ané, J. M. (2019). Are we there yet? The long walk towards the development of efficient symbiotic associations between nitrogen-fixing bacteria and non-leguminous crops. *BMC Biol.* **17**: 01-17.

Ribeiro-Barros, A. I., Silva, M. J., Moura, I., Ramalho, J. C., Máguas-Hanson, C., and Ribeiro, N. S. (2018). The potential of tree and shrub legumes in agroforestry systems. *Nitrogen Agric. Updates,* Amanullah and Shah Fahad (eds.). Intech Open. pp. 223-239.

Shah, A., Nazari, M., Antar, M., Msimbira, L. A., Naamala, J., Lyu, D., Rabileh M., Zajonc, J. and Smith, D. L. (2021). PGPR in agriculture: A sustainable approach to increasing climate change resilience. *Front. Sustain. Food Syst.* **5**: 667546. *doi: 10.3389/ fsufs.2021.667546.*

Stagnari, F., Maggio, A., Galieni, A. and Pisante, M. (2017). Multiple benefits of legumes for agriculture sustainability: An overview. *Chem. Biol. Technol. Agric.* **4**: 01-13.

Thilakarathna, M. S., McElroy, M. S., Chapagain, T., Papadopoulos, Y. A. and Raizada, M. N. (2016). Belowground nitrogen transfer from legumes to non-legumes under managed herbaceous cropping systems–A review. *Agron. Sustain. Dev.* **36**: 01-16.

Vasconcelos, M. W., Grusak, M. A., Pinto, E., Gomes, A., Ferreira, H., Balázs, B., Centofanti, T., Ntatsi, G., Savvas, D., Karkanis, A., Williams, M., Vandenberg, A., Toma, L., Shrestha, S., Akaichi, F., Barrios, C. O., Gruber, S., James, E. K., Maluk, M., Karley, A. and Iannetta, P. (2020). The biology of legumes and their agronomic, economic and social impact. In: *The Plant Family Fabaceae,* Mirza Hasanuzzaman, Susana Araújo and Sarvajeet Singh Gill (eds.). Springer, Singapore. pp. 03-25.