ISSN Print: 2664-6064
ISSN Online: 2664-6072
NAAS Rating (2026): 4.69
IJAN 2026; 8(7): 152-157
www.agriculturejournal.net
Received: 20-05-2026
Accepted: 22-06-2026

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Effect of different food-forage based cropping system on Soil Properties and Nutrient uptake influenced by different food -forage based cropping system

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DOI: https://www.doi.org/10.33545/26646064.2026.v8.i7b.727

Abstract
The present study, entitled "Production Potential and Economic Viability of Food-Forage-Based Cropping Sequences under Irrigated Conditions of Jabalpur, Madhya Pradesh," was conducted under the All India Coordinated Research Project on Forage Crops at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, and Madhya Pradesh. Ten food-forage-based cropping sequences were evaluated in a randomized block design with three replications. The cropping sequence comprising maize (green cob) + ricebean-berseem-maize (fodder) + ricebean recorded the highest total nitrogen uptake of 642.1 q/ha. The maximum total phosphorus uptake of 103.4 q/ha was observed under maize (baby corn) + ricebean-oat-maize (fodder) + ricebean, whereas the minimum uptake was recorded under the hybrid Napier-based cropping sequence. The existing rice-berseem-moong cropping sequence registered a total phosphorus uptake of 61.2 q/ha. Potassium uptake was highest under maize (baby corn) + ricebean- oat-maize (baby corn) + ricebean, with a value of 757.0 q/ha, while the lowest uptake of 435.9 q/ha was recorded under hybrid Napier + ricebean-hybrid Napier + berseem-hybrid Napier + ricebean. Changes in soil properties after the completion of two cropping cycles indicated that the evaluated cropping sequences were generally effective in maintaining soil fertility. However, the continuous cultivation of hybrid Napier showed signs of soil organic carbon depletion after two rotational cycles. The improvement in soil fertility under the remaining cropping sequences could primarily be attributed to the inclusion of leguminous crops.

Keywords: Food-forage crops, nutrient uptake, soil fertility

Introduction
Forage-based cropping systems may be equally or even more profitable than the commonly followed cropping systems of the region. Forage crops have considerable potential in contingency planning because they can be grown as short-duration catch crops, intercrops, or alley crops under different resource-use conditions. Their cultivation can support farmers' livelihoods by improving livestock productivity. Considering the increasing demand for livestock products, production strategies should focus on promoting forage-based cropping systems. Forages may also be included as sole crops, mixed crops, or intercrops within existing cropping systems to reduce the gap between forage demand and supply in accordance with prevailing agro-economic and environmental conditions (Raghuvanshi *et al.* 2023b; Dubey *et al.* 2022b; Upadhyay *et al.* 2011) [1, 2, 3]. Food-forage-based production systems can support small and marginal farmers by enabling them to allocate a proportion of their agricultural land specifically to forage production within grain-based crop rotations. Forage crops should therefore be incorporated into existing food-based cropping systems through crop intensification in space, such as intercropping, in time, such as sequential cropping, or through a combination of both approaches. Such diversification and intensification can satisfy farmers' household requirements, improve their economic returns, enhance the profitability of farming, and contribute to better soil health.

Materials and Methods
Field experiments were conducted during 2010-2011 and 2011- 2012 at the Adhartal Research Farm of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh. The investigation was undertaken under the All India Coordinated Research Project on Forage Crops.

The experiment was initiated during the kharif season of 2010-2011 and continued for two consecutive years at the same location without altering the treatment structure or experimental layout. An already established hybrid Napier crop was used under treatment T1. The experimental soil was sandy clay loam in texture and slightly alkaline in reaction, with a pH of 7.60. It contained a low level of organic carbon at 0.6% and had a normal electrical conductivity of 0.49 dS/m. The soil was low in available nitrogen at 235.8 kg/ha and medium in available phosphorus and potassium at 16.2 and 395.5 kg/ha, respectively. The experiment comprised ten food-forage cropping sequences, which were evaluated in a randomized block design with three replications. The treatment details were as follows:

- T1: Hybrid Napier + ricebean-hybrid Napier + berseem-hybrid Napier + ricebean. An established hybrid Napier crop was used.
- T2: Maize (baby corn) + ricebean-berseem-maize (baby corn) + ricebean.
- T3: Maize (baby corn) + ricebean-oat-maize (baby corn) + ricebean.
- T4: Maize (baby corn) + ricebean-berseem-maize (fodder) + ricebean.
- T5: Maize (baby corn) + ricebean-oat-maize (fodder) + ricebean.
- T6: Maize (green cob) + ricebean-berseem-maize (greenCob) + ricebean.
- T7: Maize (green cob) + ricebean-oat-maize (green cob) + ricebean.
- T8: Maize (green cob) + ricebean-berseem-maize (fodder) + ricebean.
- T9: Maize (green cob) + ricebean-oat-maize (fodder) + ricebean.
- T10: Rice-berseem-moong.

The crop varieties used in the experiment were JM-216 for baby corn, Priya Sweet Corn for green cob maize, African Tall for fodder maize, JRBJ-05-2 for ricebean, NB-1 for hybrid Napier, JB-1 for berseem, and JO-1 for oat.

Recommended fertilizer doses were applied separately to each crop. The calculated quantities of fertilizers were supplied to the respective experimental plots according to the treatments. Nitrogen, phosphorus, and potassium were applied through urea, single superphosphate, and muriate of potash, respectively. In hybrid Napier, the complete doses of phosphorus and potassium were applied as basal fertilizers during the kharif season. Nitrogen was applied in five equal splits, with one split supplied after each cutting. In rice and maize grown during the kharif and summer seasons, the entire quantities of phosphorus and potassium and onethird of the nitrogen were applied at sowing. The remaining nitrogen was top-dressed in two equal splits at 25 and 45 days after sowing. Standing water and weeds were avoided in the crop plots during nitrogen top-dressing. In summer green gram, the entire quantities of nitrogen, phosphorus, and potassium were applied in rows approximately 2 cm below the seeds at the time of sowing. As berseem was sown through broadcasting, all fertilizers were also broadcast immediately before sowing and thoroughly incorporated into the soil. In oat, half of the nitrogen and the entire doses of phosphorus and potassium were applied as basal fertilizers. The remaining half of the nitrogen was applied immediately after the first green-forage cutting to encourage rapid crop regrowth. Seed and plant samples, excluding roots, were collected at the harvest of each crop component during both years. The collected samples were oven-dried until a constant weight was obtained and subsequently ground into a fine powder using a mortar and pestle. The nitrogen content of the samples was estimated using the Nessler's reagent colorimetric method described by Linder (1944). Phosphorus was determined through the ammonium vanadomolybdophosphoric acid yellow-colour method described by Jackson (1973)[4], whereas potassium was analysed using the flame photometer method reported by Khanna *et al.* (1971). The nitrogen, phosphorus, and potassium contents of grain and straw samples were recorded separately for each treatment. Nutrient uptake was subsequently calculated using the corresponding grain and straw yields. Total nutrient uptake under each treatment was obtained by adding the nutrient uptake values of all component crops. The total uptake of nitrogen, phosphorus, and potassium by the complete cropping system was then calculated to compare the effects of the different treatments.

Results and Discussion

Effect of Cropping Sequences on Nutrient Uptake

The pooled data on total nitrogen, phosphorus, and potassium uptake under the different food-forage-based cropping sequences are presented in Table 1.

Total Nitrogen Uptake

The results demonstrated that total nitrogen uptake differed significantly among the evaluated cropping sequences. Treatment T10, consisting of rice-berseem-moong, recorded the lowest total nitrogen uptake of 386.37 q/ha/year. However, it remained statistically comparable with T1, hybrid Napier + ricebean-hybrid Napier + berseem-hybrid Napier + ricebean, which recorded 405.99 q/ha/year; T3, maize (baby corn) + ricebean-oat-maize (baby corn) + ricebean, which recorded 398.64 q/ha/year; and T7, maize (green cob) + ricebean-oat-maize (green cob) + ricebean, which recorded 396.56 q/ha/year. The highest nitrogen uptake of 642.10 q/ha/year was recorded under T8, maize (green cob) + ricebean-berseem-maize (fodder) + ricebean. It was closely followed by T4, maize (baby corn) + ricebean- berseem-maize (fodder) + ricebean, which recorded 639.76 q/ha/year. These findings are consistent with the observations reported by Tiwari *et al.* (2013) [5], Tomar *et al.* (2023a) [6], Bhalse *et al.* (2024) [7], Chauhan *et al.* (2017) [8], Dubey *et al.* (2022a) [2], and Kumhar *et al.* (2025)[9].

No significant differences in nitrogen uptake were observed among T2, maize (baby corn) + ricebean-berseem-maize (baby corn) + ricebean; T5, maize (baby corn) + ricebean-oat-maize (fodder) + ricebean; and T9, maize (green cob) + ricebean-oat-maize (fodder) + ricebean. These treatments recorded nitrogen uptake values of 531.66, 513.00, and 506.41 q/ha/year, respectively. Comparable findings have also been reported by Verma *et al.* (2016b) [10], Verma *et al.* (2024) [11], Yadav *et al.* (2023) [12], and Yadav *et al.* (2024) [13].

Total Phosphorus Uptake

With regard to total phosphorus uptake, T1, comprising hybrid Napier + ricebean-hybrid Napier + berseem-hybrid Napier + ricebean, recorded the lowest value of 57.95 q/ha/year. However, this treatment was statistically comparable with T10, rice-berseem-moong, which registered a phosphorus uptake of 61.04 q/ha/year. The highest phosphorus uptake of 103.49 q/ha/year was recorded under T5, maize (baby corn) + ricebean-oat-maize (fodder) + ricebean. This treatment was superior to all other treatments except T4, maize (baby corn) + ricebean-berseem-maize (fodder) + ricebean, which recorded a total phosphorus uptake of 100.78 q/ha/year. Similar results have been reported by Singh *et al.* (2013a) [14], Singh *et al.* (2013b) [15], Nirala *et al.* (2022) [16], Tomar *et al.* (2023b) [17], and Tiwari *et al.* (2011) [18]. The phosphorus uptake recorded under T2, maize (baby corn) + ricebean-berseem-maize (baby corn) + ricebean; T3, maize (baby corn) + ricebean-oat-maize (baby corn) + ricebean; and T7, maize (green cob) + ricebean-oat-maize (green cob) + ricebean, did not differ significantly. These treatments recorded total phosphorus uptake values of 81.02, 86.58, and 81.02 q/ha/year, respectively.

A similar trend was observed between T8, maize (green cob) + ricebean-berseem-maize (fodder) + ricebean, and T9, maize (green cob) + ricebean-oat-maize (fodder) + ricebean, which recorded phosphorus uptake values of 95.68 and 99.61 q/ha/year, respectively. In contrast, T6, maize (green cob) + ricebean-berseem-maize (green cob) + ricebean, recorded a comparatively lower phosphorus uptake of 73.73 q/ha/year. These observations are supported by the findings of Patel *et al.* (2023) [19], Sahu *et al.* (2023) [20], Raghuwanshi *et al.* (2023) [21], Shri *et al.* (2015) [22], Shrivastava *et al.* (2014) [23], and Verma *et al.* (2016a) [24].

Total Potassium Uptake

Potassium uptake was considerably higher than nitrogen and phosphorus uptake under all the evaluated cropping sequences. The lowest total potassium uptake of 435.99 q/ha/year was recorded under T1, hybrid Napier + ricebean-hybrid Napier + berseem-hybrid Napier + ricebean. It was followed by T10, rice-berseem-moong, which recorded 453.36 q/ha/year.

The highest potassium uptake of 757.08 q/ha/year was recorded under T5, maize (baby corn) + ricebean-oat-maize (fodder) + ricebean. Similar findings were reported by Tiwari *et al.* (2013) [5], Singh *et al.* (2013) [15, 14], Bhalse *et al.* (2023) [1], Bhayal *et al.* (2022) [25], Jha *et al.* (2022) [26], Jha *et al.* (2020) [27], and Tiwari *et al.* (2011b)[18, 28]. Treatment T5 recorded significantly greater potassium uptake than all the other treatments except T9, maize (green cob) + ricebean-oat-maize (fodder) + ricebean, which registered 737.80 q/ha/year.

Treatments T3, maize (baby corn) + ricebean-oat-maize (baby corn) + ricebean; T4, maize (baby corn) + ricebean-berseem-maize (fodder) + ricebean; T7, maize (green cob) + ricebean-oat-maize (green cob) + ricebean; and T8, maize (green cob) + ricebean- berseem-maize (fodder) + ricebean, recorded comparatively similar potassium uptake values of 669.97, 688.31, 637.94, and 672.44 q/ha/year, respectively.

Treatments T2, maize (baby corn) + ricebean-berseem-maize (baby corn) + ricebean, and T6, maize (green cob) + ricebean-berseem-maize (green cob) + ricebean, recorded total potassium uptake values of 597.91 and 567.98 q/ha/year, respectively. Both treatments performed better than the existing rice-berseem-moong cropping sequence. Comparable results have been documented by Kumbhare *et al.* (2023b) [29], Pahade *et al.* (2023) [30], and Sairam *et al.* (2023) [31].

Table 1: Total N, P and K uptake as influenced by different food-forage based cropping sequences

Treatment	Uptake (q/ha)								
	N			P			K		
	2010-11	2011-12	Mean	2010-11	2011-12	Mean	2010-11	2011-12	Mean
T_1 - Hybrid Napier + rice-bean - hybrid Napier + berseem - hybrid Napier + rice-bean	403.30	408.69	405.99	56.64	59.27	57.95	433.94	438.05	435.99
T_2 - Maize (BC) + rice-bean - berseem - maize (BC) + rice-bean	529.76	533.56	531.66	80.41	81.63	81.02	597.71	598.11	597.91
T_3 - Maize (BC) + rice-bean - oat - maize (BC) - rice-bean	396.78	400.51	398.64	85.88	87.28	86.58	666.92	673.02	669.97
T_4 - Maize (BC) + rice-bean - berseem - maize (F) + rice-bean	635.82	643.71	639.76	99.60	100.78	100.19	686.04	690.59	688.31
T_5 - Maize (BC) + rice-bean - oat - maize (F) + rice-bean	509.12	516.89	513.00	102.71	104.28	103.49	754.03	760.13	757.08
T_6 - Maize (GC) + rice-bean - berseem - maize (GC) + rice-bean	529.07	533.21	531.14	73.37	74.08	73.73	564.7	571.19	567.98
T_7 - Maize (GC) + rice-bean - oat - maize (GC) + rice-bean	391.73	401.39	396.56	80.09	81.95	81.02	634.36	641.52	637.94
T_8 - Maize (GC) + rice-bean - berseem - maize (F) + rice-bean	637.91	646.29	642.10	94.38	96.98	95.68	670.66	674.22	672.44
T_9 - Maize (GC) + rice-bean - oat - maize (F) - rice-bean	504.18	508.65	506.41	98.63	100.60	99.61	736.83	738.77	737.80
T_{10} - Rice - berseem - moong	383.83	388.91	386.37	60.81	61.28	61.04	451.62	455.11	453.36
SEm±	2.20	1.32	1.37	0.79	3.62	1.81	1.40	2.65	1.44
CD at 5%	6.55	3.91	4.07	2.33	10.75	5.36	4.17	7.87	4.29

Changes in soil properties

Table 2 presents the changes in the chemical properties of the soil after the completion of the cropping cycles under different crop sequences during 2010-2011 and 2011-2012, compared with their initial values.

Table 2: Soil fertility status after harvest of second experimentation

Treatment	pH	EC (dS/m)	OC (%)	Available (kg/ha)		
				N	P	K
T_1 - Hybrid Napier + rice-bean - hybrid Napier + berseem - hybrid Napier + rice-bean	7.66	0.52	0.55	236.4	16.2	398.6
T_2 - Maize (BC) + rice-bean - berseem - maize (BC) + rice-bean	7.63	0.52	0.64	250.3	16.8	410.8
T_3 - Maize (BC) + rice-bean - oat - maize (BC) - rice-bean	7.65	0.53	0.61	245.8	16.5	400.3
T_4 - Maize (BC) + rice-bean - berseem - maize (F) + rice-bean	7.64	0.53	0.62	245.3	16.5	400.5
T_5 - Maize (BC) + rice-bean - oat - maize (F) + rice-bean	7.66	0.53	0.59	244.8	16.3	398.3
T_6 - Maize (GC) + rice-bean - berseem - maize (GC) + rice-bean	7.64	0.52	0.60	246.8	16.3	401.2
T_7 - Maize (GC) + rice-bean - oat - maize (GC) + rice-bean	7.67	0.54	0.59	242.8	16.3	395.8
T_8 - Maize (GC) + rice-bean - berseem - maize (F) + rice-bean	7.65	0.52	0.60	243.0	16.4	399.0
T_9 - Maize (GC) + rice-bean - oat - maize (F) - rice-bean	7.67	0.55	0.58	239.5	16.2	395.5
T_{10} - Rice - berseem - moong	7.66	0.52	0.63	240.5	16.4	396.0
Initial status	7.60	0.49	0.60	235.8	16.2	395.5

After the completion of the experiment, a general improvement in soil organic carbon and available nitrogen was observed in cropping sequences that included berseem during the rabi season. The maize (baby corn) + ricebean-berseem-maize (baby corn) + ricebean sequence recorded 0.64% organic carbon and available nitrogen, phosphorus, and potassium levels of 250.3, 16.8, and 410.8 kg/ha, respectively.

The data on changes in soil properties after two cropping cycles indicated that all ten cropping sequences were capable of maintaining soil fertility without causing substantial deterioration (Jha *et al.* 2016; Jha *et al.* 2007; Malviya *et al.* 2012; Kumhar *et al.* 2022; Tiwari *et al.* 2011b; Tomar *et al.* 2023b) [32, 33, 34, 35, 18, 6]. The improvement in soil fertility may be attributed to the inclusion of leguminous crops in all the evaluated cropping sequences. Similar findings were reported by Jha *et al.* (2011) [36], Jha *et al.* (2023) [1], Kumar *et al.* (2023) [37], and Kumbhare *et al.* (2023a) [38].

The available phosphorus content increased marginally compared with the initial soil status under all cropping sequences. Only slight changes were observed in the available potassium content. In food-forage-based cropping sequences that included berseem, soil fertility parameters showed a modest improvement over their initial levels.

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