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Effects of organic manures and inorganic fertilizers on soil fertility and productivity of Samai-Horsegram cropping sequence in *Lithic Haplustept*

[1*]M. Vijaya kumar, [2]R. Siva kumar, and [3]N. Tamilselvan

[1] (SS&AC) in Agricultural College and Research Institute, TANU, Kudumiyanmalai, Pudukkottai, Tamil Nadu, India
[2](Crop Physiology), Tamil Nadu Agricultural University, Coimbatore, India
[3](Agronomy), Regional Research Station, Paiyur, Krishnagiri, Tamil Nadu, India

ABSTRACT

Millets are amazing in their nutrition content. Each of the millets is three to five times nutritionally superior to the widely promoted rice and wheat in terms of proteins, minerals and vitamins. Most millet farmers use farmyard manures and in recent times, household produced waste as nutrient source. Therefore, they couldn't increase the crop productivity. Combined application of organic manures and chemical fertilizers could provide higher benefit towards crop yield and soil health sustainability as compared to only application of chemical fertilizers for millets under rainfed conditions. In future, where water and food crisis stares us in the face, millets can become the food of security. By focusing of above challenges the field experiments were carried out to study on application of organic manures and chemical fertilizers in the samai-horsegram cropping system as rainfed in the non-calcareous sandy loam soils of Lithic Haplustept for two consecutive years of 2015–2016 and 2016–2017 at Regional Research Station, Tamil Nadu Agricultural University, Paiyur of Krishnagiri district. The experiment consisted of four treatments: T_1 (Control), T_2 (Organic Manuring), T_3 (Inorganic Fertilization; (RDF) Recommended Dose of N, P_2O_5, and K_2O @ 44:22:0 kg ha^{-1}), and T_4 (Integrated Nutrient Management; FYM 12.5 t ha^{-1} + Recommended Dose of N, P_2O_5, and K_2O of 44:22:0 kg ha^{-1} + Seed Treatment with Bio-Fertilizer). The samai (Little millet- Panicum sumatrense) results showed that adopting integrated nutrient management practices resulted in higher grain yields of 783 kg ha^{-1} with yield increases of 20 percent over inorganic fertilization and 25 percent over organic manure, as well as a higher B: C ratio of 2.01. Additionally, a higher total nutrient intake of 18.7, 5.3, and 21.9 kg N, P, and K ha^{-1} was observed. However, there was a considerable difference from the control plot, but there was no difference between organic manure and chemical fertilization. Similar to residual horse gram results, integrated nutrient management produced higher seed yield (498 kg ha^{-1}) with a B:C ratio of 1.85, as well as maximum plant height, number of branches, pods per plant, and seed yield per pod.

Keywords: Samai-Horsegram, INM practices, Bio-fertilizers, *Lithic Haplustept*, Soil fertility, Nutri-cereals, Organic Manure, Inorganic fertilization

1. INTRODUCTION

Small-grained millets, also known as "Nutri-cereals" or "Dryland cereals," were cultivated more than 8,000 years ago in the central Chinese highlands [9]. These crops are excellent examples of "Produces of Antiquity" because of their natural resistance to disease, pests, and drought [6]. Globally, malnutrition affects billions of people and is a severe increasing concern. Currently, 462 million persons are underweight and 1.9 billion adults are overweight or obese. Malnutrition is a grave issue both in India and elsewhere [9]. Therefore, including these nutrient-rich crops in staple diets may be a preferable option for nutritional security in order to combat the dangers of malnutrition and hidden hunger [11]. On the other hand, as the area in India planted with millets has significantly decreased over the past four to five decades, millet farming is no longer a top concern for Indian farmers. The low level of the yield of these crops is one of the main causes of the cultivators' slow adoption of millets [3] and consequently poor economic returns. The main obstacles to millet yield are thought to be nutrient and moisture stressors [10]. It is crucial to increase the yield of these crops since they are grown primarily (91%) in rainfed locations, where millet cultivation is profitable. One of the most important methods for achieving higher millet yields in rainfed areas is effective nitrogen management techniques [2].

It was seen as a component of holistic farming intended to satisfy various residential needs. Nowadays, it is widely believed that stability and aversion to risk are the key benefits of intercropping or continuous cropping. Millets as a group play a significant role in food and feed crops, particularly in the dryland farming system. Small millets are frequently planted in combination with oil seeds like niger, mustard, and castor as well as legumes/pulses including pigeon peas, dolichos, green gram, and black gram [17].

**Corresponding Author: M. Vijayakumar*
Email Address: vk85@tnau.ac.in

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Horse gram, also known as the "poor man's crop," is a common crop grown in India in climates with almost 200-700 mm of rainfall and temperatures between 20 and 35 °C. So they are described as drought-tolerant and often adaptable to a variety of soils. In Tamil Nadu, horse gram is often sown during the second week of October during the rabi season. However, Tamil Nadu does not cultivate it as a Kharif crop. Crops cultivated in the Kharif do not blossom and are primarily utilized as fodder. One of the primary causes of a plant's unwillingness to flower during the kharif season may be the formation of more tendrils. [18] So, producing samai in the kharif season followed by horsegram in the Rabi season can boost soil health and crop productivity.

The productivity of soil and crops is maintained in an integrated cropping system through the combined use of organic and inorganic materials. This strategy not only addresses nutritional inadequacies but also long-term soil health and productivity. According to recent data, farmers can benefit from integrated nutrition management [22]. Applying the right blend of organic manures and artificial fertilizers could result in output levels that are sustainable. These permanent manorial studies had two main goals: to improve soil health status and analyze the effects of organic manures and inorganic fertilizers under a continuous samai-horsegram cropping sequence.

2. Materials and methods

The "Permanent Manurial Experiment on Samai- Horsegram cropping sequence in red sandy loam soil of Krishnagiri under rainfed condition" field tests were carried out for two years (2015-2017) at RRS, Paiyur. Horsegram (Paiyur 2) and samai (Paiyur 2) were produced as the test crops, and the experiment was set up using a Randomized Block Design (RBD) with five replications. Four different fertilization methods were used in the experiment viz., T_1- control, T_2- organic manuring, T_3- inorganic fertilization; RDF (N, P_2O_5, and K_2O @ 44:22:0 kg ha^{-1}), and T_4- integrated nutrient management (FYM 12.5 t ha^{-1} + RDF (N, P_2O_5, and K_2O @ 44:22:0 kg ha^{-1}) + seed treatment with bio-fertilizer). After the harvest of Samai crops, Horsegrams were raised using the remaining nutrients to evaluate the lingering effects of organic manures and inorganic fertilizers employed for Samai. The soil at the test location was a red, non-calcareous, sandy loam of the Inceptisols (*Lithic Haplustept*) group. It had low levels of organic carbon, was readily available in N, P and K was non-saline, and was neutral in response. In a suspension of soil and water (1:2.5), the pH and EC of the soil were measured using conductometric and potentiometric techniques, respectively [8]. Organic carbon was estimated by chromic acid wet digestion method [23], available N by alkaline permanganate method [20], available P by colorimetry method [13], available K by neutral normal ammonium acetate method [19].

Seed treatment with biofertilizer

The seeds were treated with 3 packets (600 g ha^{-1}) of Azosporillum culture and 3 packets (600 g ha^{-1}) of phosphobacteria produced at TNAU, utilizing rice kanji as a binder for integrated nutrient management approaches. The crops were grown to maturity by giving need-based plant production and protection strategies and harvested. At the crop's harvest stage, the growth and yield metrics were measured. Five randomly chosen plants were observed for growth data (plant height, number of panicles per plant, and panicle length), and yield parameters (grain and straw yields) were recorded from the net plot area and represented in kg ha^{-1}. Different nutrients were examined in samples of soil and plants. The grain and haulms samples were analyzed for N by microkjeldhal digestion and distillation method [4] for P by triple acid extraction and vanadomolybdo phosphoric yellow color method [8], and for K by triple acid extraction and flame photometry [15].

3. Results and Discussion (pooled mean of 2 years)

***3.1. Biometric characters and yield of samai** (Little millet)*The findings on biometric characteristics, including plant height, the number, and length of panicles, as well as grain and straw yield, were recorded and reported in Table 1.

Table 1: Pooled mean analysis of biometric characters and yield of samai (Little millet) in the samai (Little millet) -horsegram cropping sequence of Lithic Haplustept (2015-16 & 2016-2017)

Treatment	Plant height (cm)	No. of panicles/ plant	Panicle length (cm)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Gross Retur n (Rs.)	Total Cost (Rs.)	B:C ratio
T_1- Control	83.4	5.35	22.2	425	980	13669	9590	1.43
T_2-Organic manuring	95.1	7.70	26.1	624	1297	19505	10840	1.80
T_3- Inorganic fertilization	97.2	8.40	26.4	650	1410	20427	11152	1.82
T_4- INM	104.3	9.45	27.6	783	1683	24982	12409	2.01
SEd	4.25	0.39	0.99	37.9	93.5	-	-	-
CD (p=0.05)	9.28	0.85	2.13	86.3	203	-	-	-

One of the key morphological growth parameters controlled by the added nutrients and growth regulators is plant height. The height of the plants varied from 83.4 cm to 104.3 cm. There was no discernible difference between organic manuring and chemical fertilization, even though the treatment that got INM practices recorded higher plant height; yet, it was considerably different from the control. A similar pattern in panicle length was seen. INM application positively impacted the number of panicles, which increased to 9.45 from organic, inorganic fertilizers used alone or as a control. This conforms to the findings of [22].

The combined average grain yield ranged from 425 to 783 kg ha-1; among the treatments, integrated nutrient management approaches considerably increased grain yield, with improvements of 20%, 25%, and 84% over control, organic manuring, and inorganic fertilization, respectively. The use of FYM serves as a source for the development and proliferation of microorganisms, which would have aided in the transformation of nutrients from organic to inorganic forms. Additionally, the enhanced production in INM might be the result of better soil nutrient usage, which would have ultimately improved the output [5]. Additionally, it has been noted that combining organic manures, inorganic fertilizers, and bio-fertilizers can improve crop output, maintain soil health, and lessen unfavorable environmental effects. The application of FYM 6 t ha-1 together with NPK 60:30:20 kg ha-1 produced 152% greater yield than the control, according to a field experiment carried out in Sundarbazar, Nepal, which clearly demonstrated that INM increased the productivity of foxtail millet [12].

In contrast to the control, the INM practices observed a higher B:C ratio of 2.01 followed by chemical fertilization. In light of this, it might be contended that integrated nutrient management methods (FYM 12.5 t ha-1 + Recommended dose of N, P2O5, and K2O of 44:22:0 kg ha-1 + Seed treatment with bio-fertilizer) were efficient and cost-effective. This was mostly brought about by a higher grain output and lower fertilizer and manure application costs.

3.2. Nutrient uptake of samai (Little millet)

Table 2: Pooled analysis of Nutrient uptake of samai in the samai-horsegram cropping sequence of Lithic Haplustept (2015-16 & 2016-2017)

Treatments	Grain uptake (kg ha^{-1})			Straw uptake (kg ha^{-1})			Total nutrient uptake (kg ha^{-1})		
	N	P	K	N	P	K	N	P	K
T_1- Control	2.55	0.57	3.95	6.05	1.79	9.1	8.60	2.35	13.1
T_2- Organic manuring	3.70	0.75	5.00	7.45	2.16	10.3	11.2	2.91	15.4
T_3- Inorganic fertilization	4.95	1.17	5.65	8.70	2.68	11.9	13.7	3.85	17.6
T_4- INM	6.40	1.41	6.80	10.6	3.45	14.8	17.0	4.86	21.6
SED	0.68	0.11	1.42	1.27	0.46	1.51	1.90	0.56	2.57
CD (p=0.05)	1.51	0.23	NS	2.70	0.40	3.35	3.90	0.65	3.75

The total nitrogen uptake varied from 8.6 to 17.0 kg ha-1, the total phosphorus uptake from 2.35 to 4.86 kg ha-1, and the total kilojoule uptake varied from 13.1 to 21.9 kg ha-1 (Table 2). The integrated nutrient management practices and the control practices had the highest and lowest total nutrient uptakes, respectively, among the treatments. In terms of all the nutrients, INM procedures are vastly superior to other procedures (Fig. 1). Similar results found by [21] stated that increasing nutrient intake is essential for increasing finger millet output. Any nutrient's absorption is influenced by its content and the crop's ability to produce dry matter. The relevant cause of enhanced nutrient intake may be higher nutrient content in the produce and higher biomass output of finger millet.

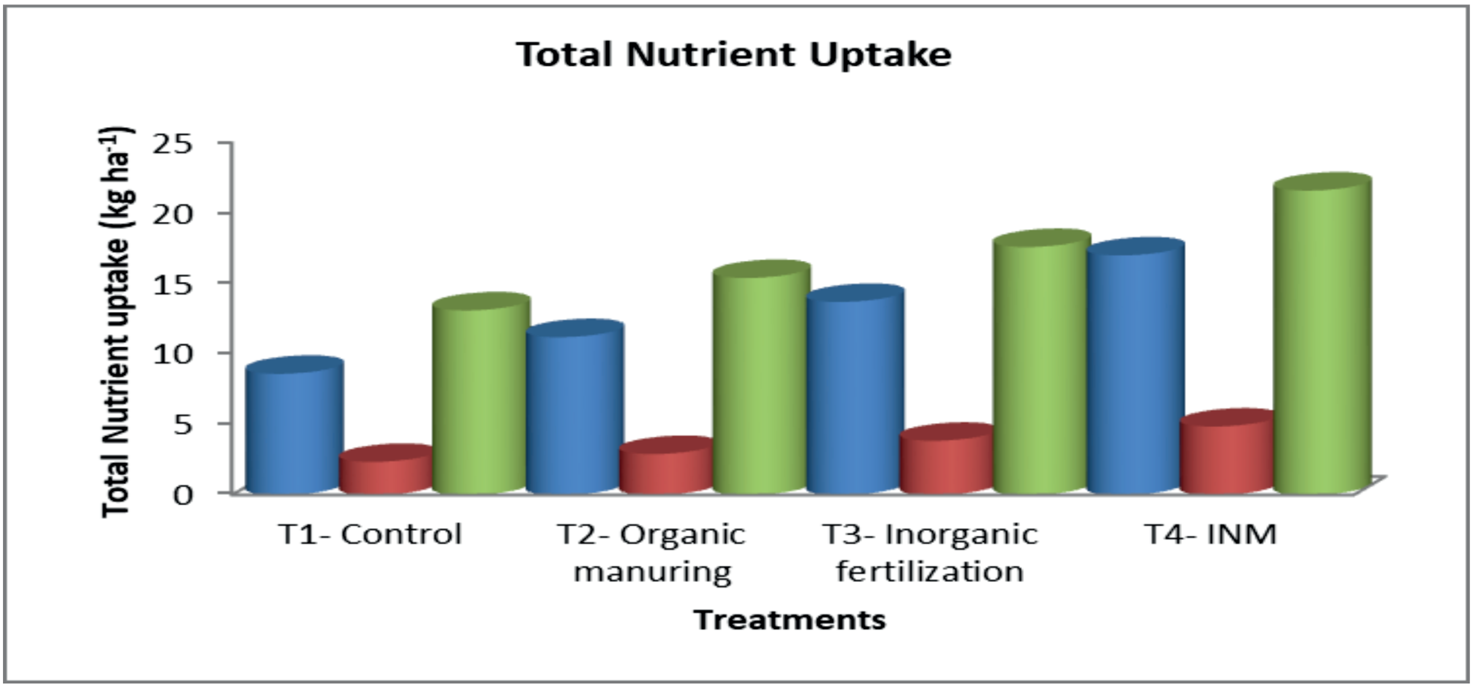

Fig.1 Total Nutrient uptake of samai (Panicum sumatrense)

[1] demonstrated that the increased uptake under INM may be attributed to the increased availability of these nutrients from the additional fertilizers as well as to the solubilizing effect of organic acids created during the breakdown of FYM, resulting in an increased release of nutrients from the soil. The addition of FYM enhanced the nutrients availability, which may have helped hybrid maize grow more quickly and produce more grain. Due to the lack of an external source of the plants' primary required nutrients, nutrient uptake was reduced in neither the plots receiving fertilizer nor manure. Hence, the lower nutrient uptake might be due to the lower grain and stover yield of the maize hybrid in the control plot [7].

3.3. Biometric characters and yield of residual horse gram

Table 3: Pooled mean analysis of biometric characters and yield of horse gram in the samai-horsegram cropping sequence of Lithic Haplustept (2015-16 & 2016-2017)

Treatment	Plant height	No. of Branches/ Plant	No. of Pod/ Plant	Grain yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Gross Return (Rs.)	Total Cost (Rs.)	B:C ratio
T_1	30.3	4.95	25.2	318	463	11340	9450	1.20
T_2	35.4	6.35	45.9	462	623	17250	9450	1.83
T_3	32.5	5.65	46.8	414	608	13140	9450	1.39
T_4	39.1	7.10	53.2	498	720	17490	9450	1.85
SED	**2.82**	**1.04**	**3.6**	**17.4**	**21.6**	-	-	-
CD(P=0.05)	**6.07**	**NS**	**8.1**	**37.8**	**46.5**	-	-	-

The findings showed that plant height, the number of branches per plant, and the number of pods per plant were significantly higher in the treatment of INM practices than in the control plot (Table 3). The haulm yield ranged from 463 to 720 kg ha-1, and the grain yield ranged from 318 to 498 kg ha-1. In integrated nutrient management and the control plot, the yields were found to be greater and lower, respectively. The seed yield of horsegram was significantly affected by integrated nutrient management practices reported by [14].

3.4. Post-harvest soil analysis

The chemical characteristics and fertility status of the post-harvest soil samples were examined, and the results are shown in Table 4. The soil's pH ranged from 7.08 to 7.18, and its EC fluctuated between 0.09 and 0.12 dS m-1. Treatments had little to no effect on the pH and EC values of the soil. The range of the accessible organic carbon was between 2.2 and 4.0 grams per kilogram. Plots undergoing integrated nutrient management strategies, which promote the growth and activity of microorganisms, had the highest levels of organic carbon. When compared to inorganic fertilization alone, continuous application of organic manures, either alone or in conjunction with it showed a larger organic carbon content [7].

Table 4: Effect of samai-horsegram cropping sequence on post-harvest soil properties

Treatments	pH	EC (dS m^{-1})	Organic carbon (g kg^{-1})	Available nutrients (kg ha^{-1})		
				N	P	K
T_1- Control	7.12	0.10	2.2	145	12.4	235
T_2- Organic manuring	7.08	0.09	3.6	184	17.3	262
T_3- Inorganic fertilization	7.18	0.11	3.2	224	19.8	267
T_4- INM	7.11	0.12	4.0	250	21.0	290

Between absolute control and INM techniques, the available nitrogen ranged from 145 kg ha^{-1} to 250 kg ha^{-1}. N mineralization from organic sources may be to blame for the rise in accessible N content with the addition of organic sources. [22] also reported that an application of organic manure would multiply soil microbes, which would enhance the conversion of organically bound nitrogen into inorganic forms, prompt mineralization, and increase the amount of available nitrogen that is available to the crops in addition to the recommended dose of fertilizers. The control value had the lowest value. Continuous crop removal without external fertilizer addition or FYM over time led to a reduction in soil available N.

The available phosphorus ranged from 12.4 kg ha^{-1} in control to 21.0 kg ha^{-1} in INM practices. The solubilization of phosphorus by the organic acids released from the organic manures, the decrease in phosphorus fixation in the soil as a result of the chelation of P-fixing cations like Fe, Al, Zn, Mn, and Cu, as well as the increased microbial activity, may be responsible for the higher availability of phosphorus in INM treatment. A crucial ingredient that promotes plant growth and development is phosphorus (P). Adenosine triphosphate (ATP), which is the energy unit of plants and contains P in its structure, is created during the photosynthetic process. As with applied N, other experiments have shown that applying P increases foxtail millet yield [16]. The additional dose of K through 12.5 t of FYM applied annually, which could supply 62.5 kg ha^{-1} of K, and the interaction of clay with potassium and bio-fertilizers boost potassium availability can both be credited for the increased potassium availability in INM treatment.

4. Conclusion

The findings of the current experiment showed that the use of INM techniques resulted in higher seed production of 783 kg ha-1 and an increase in output of 20% over inorganic fertilization and 25% over organic manuring alone. Application of organic manure or fertilizer, either separately or in combination, demonstrated their effectiveness in raising samai (Little millet) yields relative to absolute control. The total N uptake ranged from 8.6 kg ha^{-1} to 18.7 kg ha^{-1}. The P uptake varied from 2.1 to 5.3 kg ha^{-1} and the K uptake was in the range of 13.5 to 21.9 kg ha^{-1} among the treatments. The INM practices are significantly different from other treatments, and the least and highest uptake was observed in the control and INM practices, respectively. INM methods had the highest B:C ratio (2.01), which was then followed by treatments using inorganic fertilizers and organic manuring. Combined application of organic manures and chemical fertilizers could provide higher benefit towards crop yield and soil health sustainability as compared to only application of chemical fertilizers for millets under rainfed conditions.

Future scope of the study: In future, assessment of soil biological properties and quality should be linked to the farmer's perceptions and circumstances to provide a realistic approach to soil quality and fertility management which makes the adoption of measures for the sustainable farming.

Conflict of interest: The authors declare no conflict of interest.

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