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Sustaining Productivity, Available Nutrient and Microbial Status of Soil through INM in Pearlmillet (*Pennisetum glaucum* L.) -Wheat (*Triticum aestivum* L.) Cropping System

Amit Kumar*, Pawan Kumar, Mukesh Kumar and Naresh Kumar

Department of Agronomy, CCS Haryana Agricultural University, Hisar-125004 India

*Corresponding Author E-mail: amitsodhi1986@gmail.com

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ABSTRACT

A field experiment was conducted at CCS Haryana Agricultural University, Hisar during 2009-10 to evaluate the influence of INM in Pearlmillet (Pennisetum glaucum L.)-Wheat (Triticum aestivum L.) cropping system on productivity, available nutrient status and microbial status of soil. Experiment consisting of 12 treatment combinations viz., T_1- control (no fertilizer): T_2 -, 50% recommended NPK to pearlmillet and wheat: T_3 - 50% recommended NPK to pearlmillet and 100% recommended NPK to wheat; T_4 - 75% recommended NPK to pearlmillet and wheat; T_5 - 100% recommended NPK to pearlmillet and wheat; T_6 - 50% NPK + 50% N (farmyard manure) to pearlmillet and 100% recommended NPK to wheat; T_7 - 75% NPK + 25% N (farmyard manure) to pearlmillet and 75% recommended NPK to wheat; T_8 - 50% NPK + 50% N (wheat straw) to pearlmillet and 100% recommended NPK to wheat; T_9 - 75% NPK + 25% N (wheat straw) to pearlmillet and 75% recommended NPK to wheat; T_{10} - 50% NPK + 50% N (Sesbania spp.) to pearlmillet and 100% recommended NPK to wheat; T_{11} - 75% NPK + 25% N (Sesbania spp.) to pearlmillet and 75% recommended NPK to wheat and T_{12}- farmers' practice laid out in randomized block design. Results of the experiment show that integrated nutrient supply improve the productivity of Wheat- Pearlmillet cropping system and enhance the microbes' counts and establishment of soil.

Key words: *Pearlmillet-Wheat, Cropping System, INM, FYM, Nutrient Status, Microbial Status*

INTRODUCTION

Fertilizer (nutrient) is the key element that can be effectively managed to get desired use efficiency under a given situation. Higher food production needs balance amount of plant nutrients. Without careful management, manures can cause yield loss and lower crop quality as a result of both under and over fertilization. To avoid wastage of resources and to minimize the environmental damage there is a need to develop and demonstrate balanced use of organic/inorganic fertilizers. This will not only improve the crop production in sustainable way but also economise the crop production.

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As no single source is capable of supplying the balanced amount of nutrients, integrated use of all sources is a must to supply balanced nutrients to plants[6]. Pearlmillet (*Pennisetum glaucum* L.) - Wheat (*Triticum aestivum* L.) is one of the important cropping systems of the country and spreads over (i) arid eco-region comprising, western plains, Kachh and parts of Kathiawar Peninsula having desert and saline soils representing Gujarat, Rajasthan and Haryana; (ii) semi-arid eco-region comprising northern plains of Haryana, western Uttar Pradesh and central high lands of Rajasthan with alluvium derived soils. This system is very exhaustive and a crop giving 2.9 tones per hactare of pearlmillet and 4.2 tones per hactare of wheat which may remove 238, 54 and 131 kg nitrogen, phosphorus and potassium per hactare, respectively[7]. Fertility of soil is very important for obtaining optimum production of crops. The role of organic matter in enhancing and maintaining soil fertility and productivity is universally understood. The absence of organic matter from soil causes unproductive soil. Organic matter induces life into the soil and sustains biological life. In order to attain sustained production of crops, recycling of organic matter in the soil should become a regular feature of modern agriculture[3]. The almost complete reliance on the use of chemical fertilizer, ignoring bio-organic material has in the course of time brought in focus a number of problems such as, wide spread deficiencies of nutrients and decline in the productivity of crops and increasing the environmental pollution[9].

During last five decades, the food grain production increased by five folds from a low of 50.82 mt in 1950-51 to 252.22 mt in 2015-16 and consumption of fertilizer (N+P+K) has increased from 0.07 to 26.76 mt (in nutrient terms) over the same period. A consumption of 26.76 mt of nutrients comprising 17.37 mt of nitrogen, 6.98 mt of phosphorus and 2.4 mt of potash. Consumption of fertilizers (all nutrients) per hectare increased from 1.0 kg to 150.5 kg in 2014-15[1]. Long term studies being carried out at several locations on different cropping systems indicated that application of all the needed nutrients through chemical fertilizers has deleterious effect on soil health, leading to unsustainable yields[16,2]. This further has led to aggravated micro-nutrient deficiency in soil system.

Since, the nutrient turnover in soil-plant system is considerably high under intensive cropping system. So, neither the chemical fertilizers nor the organic/biological sources alone can achieve production sustainability. Even with the so called balance use of NPK fertilizers in long term studies, higher yield levels could not be maintained for years because of emergence of secondary and micro-nutrient deficiency and deterioration in the soil physical environment. Whereas, organic manure alone or in combination with inorganic fertilizers is known to have favorable effect on soil environment and correct marginal deficiency of secondary and micro-nutrients and enhance efficiency of applied nutrients. Therefore, there is need to improve nutrient supply system for sustainable production of this very important cropping system of India.

Increase in microbial population in the rhizosphere of both soybean and wheat crop in presence of organics is obvious and they act as a source of energy. Integrated use of organics with chemical fertilizers, ameliorate the soil and improve the productivity of crop, resulting in eco-friendly farming system[11]. For higher fertilizer use efficiency and sustainability of cropping system, there is need to recommend and develop site specific nutrient management strategies considering the cropping system as a whole, instead of component crops in isolation[12,15]. To achieve this, we have to take into account the direct as well as residual effect of fertilizer to different crops in the system.

MATERIALS AND METHODS

The field experiment was carried out at Agronomy Research Area at CCS Haryana Agricultural University, Hisar during 2009-10. The soil of experiment site was sandy loam in

texture. The experiment was laid out in randomized block design with 12 treatments combinations replicated four times. The treatments were: T_1 - control (no fertilizer): T_2 - 50% recommended NPK to pearlmillet and wheat: T_3 - 50% recommended NPK to pearlmillet and 100% recommended NPK to wheat; T_4 - 75% recommended NPK to pearlmillet and wheat; T_5 - 100% recommended NPK to pearlmillet and wheat; T_6 - 50% NPK + 50% N through farmyard manure (FYM) to pearlmillet and 100% recommended NPK to wheat; T_7 - 75% NPK + 25% N through FYM to pearlmillet and 75% recommended NPK to wheat; T_8 - 50% NPK + 50% N through wheat straw to pearlmillet and 100% recommended NPK to wheat; T_9 - 75% NPK + 25% N through wheat straw to pearlmillet and 75% recommended NPK to wheat; T_{10} - 50% NPK + 50% N through *Sesbania* spp. to pearlmillet and 100% recommended NPK to wheat; T_{11} - 75% NPK + 25% N through *Sesbania* spp. to pearlmillet and 75% recommended NPK to wheat and T_{12} - farmers' practice.

The recommended levels of N and P_2O_5 were 125 and 62.5 kg ha^{-1} for pearlmillet and 150 and 60 kg ha^{-1} wheat. The farmers' practice based on state average was 116 kg ha^{-1} N for pearlmillet. In wheat the farmers' practice based on state average was 138.75 kg ha^{-1} for N and 54.75 kg ha^{-1} for P_2O_5. The pearlmillet variety used was HHB-197 with 5 kg ha^{-1}, keeping intra row spacing of 10 cm and inter row spacing 45 cm. In wheat variety PBW-502 was sown with 100 kg seed ha^{-1} keeping inter row spacing of 20 cm. Pearlmillet was sown on June 21, 2009 and was harvested on September 6, 2009. Similarly, wheat was sown on November 2, 2009 and was harvested on April 11, 2010. The N content in different organic materials was determined and the amount of these materials required for substituting a specified amount of N as per the treatment was calculated. The organic sources of nutrients *viz.*, FYM, wheat straw and green manure were incorporated in soil 40, 43 and 36 days, respectively, before sowing pearmillet crop. The recommended N and P_2O_5 were applied through urea and DAP, respectively. Three post sowing irrigations were applied in pearlmillet. Similarly in wheat four irrigations were applied. Recommended package of practices were followed in both the crops for other agronomic operations. The grain and stover/straw yield was recorded after harvesting the crop. Microbial studies of soil were done after harvest of wheat crop. This study includes the counts and establishment (cfu/g soil) of microbes' *viz*. *Azotobacter*, Total Bacteria, *Azosipillum* and Phosphate solublizers with the help of growth media *i.e.* Jensen media, Malate, Nutrient Agar and Pikovaskaya, respectively.

RESULTS AND DISCUSSION

Productivity

The results of the study (Table 1) revealed that treatment T_6 recorded 258 and 22% higher grain yield (3644 kg ha^{-1}) of pearlmillet over T_1 (control) and T_{12} (farmers' practice) and significantly better over rest of the other treatments except treatment T_5 and T_{11}. Similarly stover yield was also recorded highest in treatment T_6. Corroborative findings have also been reported by Dahiya *et al*[4]. These two parameters also increased with higher doses of inorganic fertilizers. This might be due to easy availability of plant nutrients and higher photosynthetic activities as compared to under dose fertilized treatments. Replacement of 50% N through FYM also results into higher grain and stover yields of pearlmillet. This increase in stover probably due to more dry matter accumulation. The results are in conformity with the findings of Kumar *et al*.[13], who reported that in total production of the system; only farm yard manure could replace 50 per cent nitrogen need of pearlmillet without much adverse effect on its production. Similarly in wheat, treatment T_6 was recorded 435 and 13% higher grain yield (5922 kg ha^{-1}) over control and farmers' practice respectively, indicating that 50% N can be supplemented through FYM in pearlmillet-wheat cropping system. The results are in confirmation to the findings of Katyal *et al.*[10] and Jain and Poonia[8].

Soil fertility

The nitrogen and phosphorus balance in general was higher in integrated nutrient management treatments as compared to inorganic treatments after the harvest of both pearlmillet and wheat. The amount of nitrogen and phosphorus balance declined in treatments where these fertilizers were not applied (Table 2). Results depicted that after the harvest of pearlmillet, minimum available nitrogen of 122.5 kg ha^{-1} was recorded in control whereas, maximum available nitrogen of 192.5 kg ha^{-1} was recorded in treatment T_6. The available phosphorous status increased with increase in fertilizer dose and ranged between 13.5 to 19.2 kg ha^{-1} among different treatments being minimum in control and maximum in treatment T_6 where 50% nitrogen was substituted by FYM in *kharif*. After the harvest of wheat, the available nitrogen and phosphorus in soil were highest in same treatment T_6 and values were 234.5 and 17.5 kg ha^{-1}, respectively. The range of nitrogen and phosphorus among different treatments was between 150.5 to 234.5 and 10.0 to 17.5 kg ha^{-1}, respectively. All the fertility indicators increased with increase in nutrients dose irrespective of sources. Similar findings have been reported by Satyajeet *et al*.,[14] they reported that amount of nitrogen and phosphorus declined in plots where these fertilizers were not applied.

Microbial status

At 100% RD-NPK in wheat and where FYM was applied in pearlmillet (T_6) was recorded highest counts and establishment of *Azotobacter* and *Azospirillum* i.e. $90x10^3$ and $50x10^5$ cfu/g soil respectively (Table 3). At 100% RD-NPK in wheat and where green manure was applied in pearlmillet (T_{10}) highest total bacteria counts were observed. At 75% RD-NPK in wheat and where green manure was applied (T_{11}) maximum number ($80x10^3$ cfu/g soil) of colonies of phosphate solublizer was recorded. These results collaborate with the finding of Gawai and Pawar[5]. Soil microbes' growth and activities depends upon factors *viz.* organic matter of soil, air, moisture, temperature, light etc. Organic matter provides the shelter and feed for these micro-organisms, so soil having higher level of organic matter will be higher counts and establishment. From the results, it was evident that highest counts of microbes (*Azotobacter*, *Azospirillum*, Phosphate solublizer and Total Bacteria) were recorded in integrated nutrient management treatments in comparison to chemical fertilizer treatment and these were followed with treatments receiving organic sources of nutrients in sequence (FYM> wheat straw> green manure; Green manure> wheat straw> FYM; FYM > green manure> wheat straw and Green manure> FYM > wheat straw), respectively.

Table 1: Effect of different treatments on grain and stover/straw yield (kg ha^{-1}) of pearlmillet and wheat

Treatments	Pearlmillet		Wheat	
	Grain yield	Stover yield	Grain yield	Straw yield
T_1	1018	2862	1106	1247
T_2	2348	4637	3812	4270
T_3	2506	6515	5418	6216
T_4	2967	7402	4716	5287
T_5	3472	8538	5738	6452
T_6	3644	9025	5922	6617
T_7	3356	8272	4933	5538
T_8	2884	7070	5564	6260
T_9	3028	7508	4772	5381
T_{10}	3364	7935	5767	6466
T_{11}	3482	8602	4784	5409
T_{12}	2993	7596	5256	6155
SEm ±	**70.12**	**182.44**	**73.12**	**78.45**
CD (P=0.05)	**208.54**	**541.89**	**217.42**	**225.23**

Table 2: Soil fertility status in terms of available N and P_2O_5 (kg ha^{-1}) during the experiment

Treatments	Available N (kg ha^{-1})			Available P_2O_5 (kg ha^{-1})		
	Initial	After harvest of pealmillet	After harvest of wheat	Initial	After harvest of pealmillet	After harvest of wheat
T_1	154.0	122.5	150.5	9.5	13.5	10.0
T_2	166.3	143.5	159.3	10.0	14.0	10.5
T_3	192.5	152.2	186.3	13.5	13.5	13.5
T_4	194.3	161.0	196.0	13.5	15.0	14.0
T_5	236.3	185.5	229.3	16.0	18.5	16.0
T_6	239.8	192.5	234.5	17.5	19.2	17.5
T_7	215.3	180.2	210.0	16.5	17.5	15.5
T_8	220.5	171.5	218.8	16.5	15.0	15.0
T_9	215.3	171.5	206.5	16.0	14.0	14.0
T_{10}	213.5	171.5	224.0	14.5	17.5	17.0
T_{11}	218.5	169.7	213.5	16.0	18.5	16.0
T_{12}	217.0	154.0	215.3	14.0	15.0	13.0

Table 3: Effect of different treatments on microbial status of soil

Treatments	cfu*/g soil			
	Azotobacter	Total Bacteria	*Azospirillum*	Phosphate solublizers
T_1	$3x10^3$	$4x10^7$	$2x10^5$	$1x10^3$
T_2	$5x10^3$	$8x10^7$	$6x10^5$	$3x10^3$
T_3	$6x10^3$	$5x10^7$	$4x10^5$	$2x10^3$
T_4	$65x10^3$	$8x10^7$	$5x10^5$	$7x10^3$
T_5	$40x10^3$	$7x10^7$	$4.5x10^5$	$6x10^3$
T_6	$90x10^3$	$10x10^7$	$50x10^5$	$55x10^3$
T_7	$80x10^3$	$25x10^7$	$30x10^5$	$20x10^3$
T_8	$70x10^3$	$30x10^7$	$20x10^5$	$10x10^3$
T_9	$60x10^3$	$25x10^7$	$10x10^5$	$30x10^3$
T_{10}	$55x10^3$	$40x10^7$	$30x10^5$	$50x10^3$
T_{11}	$50x10^3$	$35x10^7$	$10x10^5$	$80x10^3$
T_{12}	$4x10^3$	$6x10^7$	$3x10^5$	$5 x10^3$

(* Colony forming unit)

CONCLUSION

Result of the experiment conclude that treatment T_6 (50% NPK + 50% N through FYM to pearlmillet and 100% recommended NPK to wheat) results better in comparison to sole application of chemical fertilizer to both crop as well as to inclusion of other organic source in terms of system yield and available nutrient balance of soil. Use of integrated nutrient management yields maximum counts and establishment of microbes in soil rather than sole application of chemical fertilizer treatments.

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