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Enhancing Soil Fertility through Intercropping, Inoculation and Fertilizer

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Abstract. The present study was conducted to investigate the effects of intercropping grass (*Panicum maximum*) and legumes (*Vicia sativa* and cowpeas) alone or coupled with inoculation or fertilizer on soil fertility. The study comprised of two field experiments conducted under rain fed conditions for two years (June, 2005 to September, 2007) at National Agriculture Research Centre, Islamabad, Pakistan. In one experiment intercropping (33, 50 and 67%) of grass and legumes alone as well as coupled with seed inoculation were studied while, same set of treatments was combined with fertilizer application at the rates of 25, 75 and 50 kg/ha (N, P_2O_5 and K_2O) in the second experiment. Total soil N increased by 0.008% due to symbiotic fixation in addition to plant uptake under best treatment when compared with grass alone while, soil organic matter increased by 0.19%. After crop harvest soil N content was determined to be higher in all the treatments of the experiment compared with growing grass alone. Legumes caused rhizobial N fixation that caused an increase in soil N. Similarly, intercropping and inoculation increased this soil characteristic that was found to be non-significant in the first crop but later on became significant, especially when intercropping of grass with legumes after seed inoculation was investigated or fertilizer was supplemented to the crops. Thus, not only grass used the symbiotically fixed N by companion legumes but also enhanced the soil N content. The effect of fertilizer was not measurable statistically in case of soil organic matter. This parameter, in general, was not affected significantly when assessed after first crop harvest. Nevertheless, legumes alone or intercropped within grass increased this important soil constituent. Inoculation proved further beneficial in this regard but combination of intercropping (especially 67%) either with seed inoculation or application of fertilizer was found as the best technique for increasing soil organic matter.

Keywords: soil fertility, *Panicum maximum,* forage legumes , intercropping, inoculation, fertilizer application

Introduction

Grasses are an important component of Graminae family. Apart from cereals, many grass species provide forage for livestock, protect the soil from erosion, improve soil structure and hence water retention (Ahmad *et al.,* 2001). The grass species *Panicum maximum* var. Tanzani is a tall growing (2-3 m), vigorous, coarse, tufted perennial and shows considerable variation in growth habit. It is a native grass of tropical and sub-tropical Africa but has been introduced in more humid tropics and sub-tropics throughout the world. Vetches (*Vicia* species) are legumes which are well adapted to winter growth in Mediterranean environments throughout the world on a variety of soil types and are used in West Asia and Australia for various purposes as green forage, hay, seed crop or green manure. Cowpeas (the legume species *Vigna unguiculata*) native to South Asia are known for their diverse distribution and range of adoption from the humid sub-tropical to warmed cool temperate climate. It contains higher protein contents, amino acids and vitamins (Bose and Balakarishnan, 2001). Low rhizobial population is the main cause of low legume yield in these areas. The use of inoculation is very low; just below 1-3% of the total area under legumes which is negligible (Aslam *et al.,* 2000). When a legume is introduced in a new locality, it is necessary to inoculate seed with proper rhizobium culture otherwise crop may not thrive and produce nodules. These bacteria although

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present in most of the soil, vary in number, effectiveness in nodulation and N-fixation (Zamaurd *et al.,* 2006). Symbiotic nitrogen fixing bacteria (SNB) are root nodule bacteria and fix nitrogen in association with leguminous plants. Biofertilizers (inoculation material) are apparently environmental friendly, low cost, non bulky agricultural inputs which could play a significant role in plant nutrition as a supplementary and complementary factor to mineral nutrition (Sahai, 1990). It is an attempt to increase nitrogen fixation and the yield at all the sites of harsh climate. Therefore, it is possible to increase nodulation causing improvement in yield from marginal lands by inoculation with rhizobium (Aslam *et al.,* 1990). Thus, keeping in view the limitations and constraints faced by the farmers busy in livestock production, a comprehensive study was conducted to monitor effect of grass-legumes intercropping, inoculation or fertilizer application on soil fertility status.

Materials and Methods

The study comprised of two field experiments conducted under rain fed conditions for two years (2005-2006 & 2006-2007) in the experimental area of Rangeland Research Programme, National Agriculture Research Centre Islamabad, Pakistan (Altitude=518 m, longitude = 73° 08'E & latitude = 33° 42'N). The experimental site is situated in sub-humid, sub-tropical region. There were two separate experiments of the study. Soil samples were prepared and analyzed before sowing having soil pH 8.4; ECe 0.53 dS/m; total N 0.037%; available P 4.7 mg/kg; extractable K 79.6 mg/kg; orgamic matter (OM) 0.53% and textural class was sandy clay loam. *Panicum maximum* grass was planted in 2005 as perennial fodder. After its establishment, winter legume (*Vicia sativa)* commonly known as vetch and summer legume (*Vigna unguiculata*) commonly known as cow peas, were sown as inter crop in the established grass but after its harvesting. Summer legume followed winter legume in the next year. Two lines of legumes with four lines of grass were grown to establish T_3 (33 % legumes) while there were three lines of each in case of T_4 (50 % legumes). In case of T_5, four lines of legumes were grown with two lines of grass to obtain the share of 67 % of the former. Seeds of legumes were inoculated before sowing to obtain T_6 to T_9. The experiment was conducted under rain fed conditions and no irrigation was applied. There was also no fertilizer application either to grass or legumes. Soil samples were obtained from each treatment separately after harvesting of fodder crops and analyzed for different parameters. Methodology for this experiment was almost the same as described under experiment 1. However, fertilizer as a basal dose was applied to the treatments T_6 to T_{10} at the rates of 25, 75 and 50 kg/ha (N, P_2O_5 and K_2O) as urea, single super posphate and sulphate of potash, respectively. Both the experiments were laid out using randomized complete block designs (RCBD) with 4 replications. Soil samples were collected from 0-15 cm after harvesting grass and legumes from all the treatment plots. The samples were air dried, ground and passed, through 2 mm sieve. Soil nitrogen was estimated through sulphuric acid digestion. Distillation was made with micro-Kjeldhal method (AOAC, 1990). Organic matter was determined by applying the following formula:

$$\text{Organic matter in \%} = \text{Organic carbon in \%} \times 1.72$$

Data were analyzed using one-way analysis of variance with the help of software package of MSTAT-C Microcomputer programme, Version 1.3. A least significant difference (LSD) was applied for multiple comparisons (Bicker, 1993).

Results and Discussion

Nitrogen is essential for plant growth as it is a constituent of all proteins and nucleic acids and hence, of all types of protoplasm. The effect of nitrogen in increasing biomass is not only due to its direct effect on the plant growth as structural constituents but also because of rapid synthesis of carbohydrates that are converted to proteins and ultimately to protoplasm when N supply is in ample quantities. The original status of total N was very low because soil analysis indicated its numerical value just as 0.037% (Table1) and response of symbiotic N fixation by rhizobia on legumes was expected because their activity becomes rapid when soil has clear deficit of N. Non-significant performance was observed after the harvest of first crop. However, legume alone had

Table 1. Original soil analysis of experimental site

Determinations	Values
pH_s	8.4
EC_e (dS/m)	0.53
Sand (%)	61
Silt (%)	12
Clay (%)	27
Textural class	Sandy clay
Organic matter (%)	0.53
Total N (%)	0.037
Available P (mg/kg)	4.70
Extractable K (mg/kg)	79.6

slightly more nitrogen than grass alone due to symbiotic nitrogen fixation effect. Intercropping of grass and legumes increased very small N percentage and more N percentage increase was also determined by combination of intercropping and inoculation (Fig. 1). Nevertheless, significant pattern of variation was observed after 2nd, 3rd and 4th crop harvest by all three planting geometries (33, 50 and 67%). The intercropping of 67% increased total N as the highest. Combinations of intercropping and inoculation had more effect on soil nitrogen but it was not found significant. This may be due to consumption of fixed N by the grass under nitrogen deficit conditions. There was a significant difference between legumes and grass alone and inoculation further departed this variation. This revealed clear effect of legumes that were successful to increase soil N as well along with meeting their own requirements. The root nodulation and fixation of atmospheric nitrogen by rhizobia was its only cause. Frame *et al.* (2005) also certified N_2 fixation of forage legumes in terms of rhizobial efficiency, N transference to associated companion grasses. The most widespread and consistent effect of legumes is to improve the N economy of soil through N_2 fixation. The N-balance of legume-cereal sequence in most cases is more positive than that of a cereal-cereal sequence in the same soil. Nitrogen fertility inevitably accompanies intensive agriculture and, at least, reduces the requirements of inputs of fertilizer N (Muhammad *et al.,* 2003). Biological nitrogen fixation occurs mainly through symbiotic association of legumes and some woody species with certain N_2-fixing micro-organisms that convert elemental nitrogen into ammonia (Serraj*,* 2004). Xia-Yan *et al.* (2006); Reynolds and Frame (2005); Vasilev (2004); Shisany (2003); Zhang and Li (2003); Abbas *et al.* (2001) and Odhiambo and Bombee (2001) also reported the increase in N_2 by intercropping along with inoculation of legume seeds. The overall input of nitrogen into global agriculture for food and feed production is estimated to be approximately 120 million tonnes/year. Biological nitrogen fixation (BNF) accounts for 40 million tonnes/year while 80 million tonnes/year is accounted for by N-fertilizer production from ammonia. In cereal production, fertilizer use dominates because if cereals were able to "fix" their own nitrogen the situation could be very different.

Addition of fertilizer to grass added nothing in soil N during first two crops but significant increase was recorded during last two crops. Maximum values were observed when intercropping was introduced up to the extent of 67% and fertilizer was supplemented (Fig. 2). However, these values of soil N were still found similar with legumes alone. Glacomini *et al.* (2003) concluded that cultivation of oat, common vetch and oil seed radish was more efficient than single crops since it combined the high biomass production capacity of black oat and oil seed radish with the ability of common vetch to fix atmospheric N_2. Geherman and Parol (2004) reported that fertilizer application was one of the main factors affecting the yield of sown pastures by the maximum utilization of readily available nutrients to the crops. Bogomolv and Petrakova (2001) recorded that the use of fodder legumes in the grass helped the reduction of mineral N fertilizer application on energy.

Fertilizer application, intercropping of legumes with grass and combining of intercropping and fertilization showed non-significant performance in all the treatments (Fig. 2).

The original status of organic matter (OM) was very poor (0.53%) (Table1). Non-significant differences were noticed within all the treatments after the harvest of first crop. However, growing of legume or its

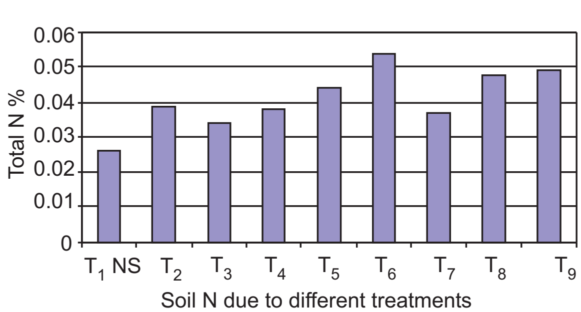

Fig. 1. Changes in soil N due to grass-legumes intercropping and inoculation (n=4, SD = 0.01).

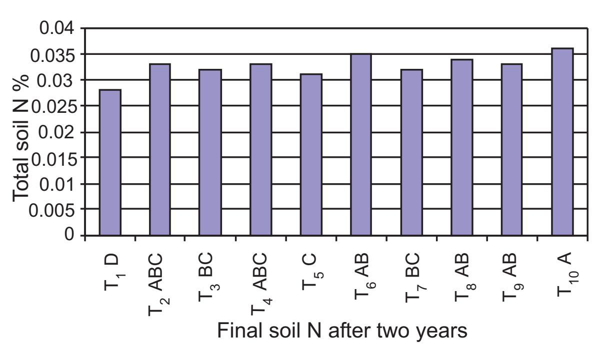

Fig. 2. Effect of intercropping (grass-legumes) and fertilizer after two years on soil nitrogen (n=4, SD = 0.003).

intercropping with grass in subsequent three crops increased soil OM that was significant with 67% intercropping or legume alone. Whereas, inoculation further increased efficiency of intercropping of 33 and 50% in statistical terms, although even OM values were also higher in treatments of legumes alone and 67% intercropping as well. A constant increase in OM content of soil with gradual growing of legumes or intercropping was recorded while the values remained almost the same in case of grass only. The end values were higher in intercropping treatments alone or when these were combined with inoculation (Fig. 3).

Soil organic improves physical condition of soil and increases water holding capacity. Finally, it is the main source of energy for soil microorganisms. Effect of organic matter was noted to be increasing one due to growing of legumes, intercropping of legumes with grass and application of fertilizer but became significant only with combination of intercropping by 67% and fertilizer application when compared with growing of grass alone during first two crops (Fig.1-4). However, during the later two crops legumes alone, intercropping and fertilization became significant except intercropping of 33%. Maximum values were recorded when intercropping of 67% was coupled with fertilizer application (Fig 4). Addition of more crop residues due to increased biomass production in different treatments could only be the reason for enhancement of organic matter status. Goddard *et al.* (2003) concluded that forage legumes played an important role in the production of organic matter in legume alone as well as legume-grass mixed sown pastures that resulted in increase in biomass production.

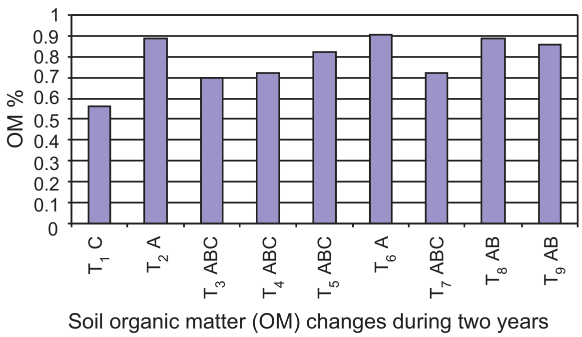

Fig. 3. Variations in soil organic matter due to grass-legumes intercropping and inoculation (n=4 SD = 0.01).

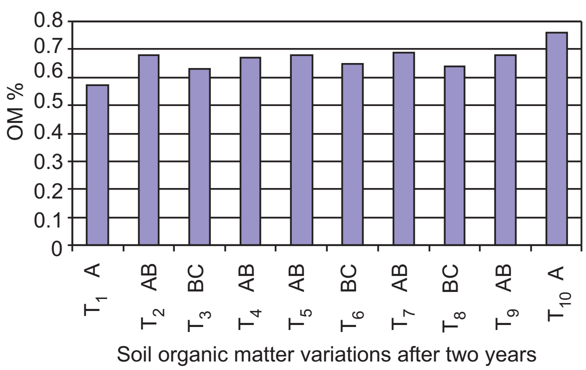

Fig. 4. Effect of intercropping (grass-legumes) and fertilizer after two years on soil organic matter (n = 4, SD = 0.01).

Conclusion

This protocol concluded that intercropping of grass and legumes, inoculation, fertilizer application and their different combinations significantly increase organic matter after second crop. Total soil N was also enhanced, especially where legumes were grown alone or intercropped because of symbiotic atmospheric nitrogen fixation. These techniques were successful to meet plant nutritional requirements because a good biomass production was obtained even in soil highly deficient for supply of nutrients.

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