PERFORMANCE OF SUMMER FORAGE LEGUMES AND THEIR RESIDUAL EFFECT ON SUBSEQUENT OAT CROP IN SUBTROPICAL SUBHUMID POTHWAR, PAKISTAN

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ABSTRACT:- The present study was conducted to assess the performance of five tropical forage legumes namely sesbania (*Sesbania aculeata*), cowpeas (*Vigna unguiculata*), rice beans (*Vigna umbellata*), lablab bean (*Lablab purpureus*) and cluster bean (*Cymopsis tetragonoloba*) with reference to a cereal fodder reference crop of millet (*Pennisetum typhoides*) and their residual effects on the succeeding oat crop at the National Agricultural Research Centre, Islamabad, Pakistan, under rainfed conditions without application of fertilizers in Randomized Complete Block Design. The highest dry matter yield was obtained from millet (8.9 tha^{-1}), followed by cowpeas (4.5 tha^{-1}), sesbania (4.4 tha^{-1}), rice beans (2.9 tha^{-1}), lablab bean (2.2 tha^{-1}) while cluster bean produced lowest dry matter (1.7 tha^{-1}). Cluster bean had the highest crude protein content (23.2 %) followed by cowpea (22.6 %), lablab bean (21.6 %), rice bean (20.1 %) and sesbania (19.1 %). Millet had the lowest crude protein content of 6.2%. Dry matter yield of oats owing to the previous crops was least after millet (7.5 tha^{-1}) and ranged from 8.5 to 8.9 tha^{-1} after sesbania, cluster bean and cowpeas. Differences in crude protein content of oats as affected by the previous crops were non-significant and ranged from 9.4% to 9.7%. Differences in crude protein yield of oats as affected by the preceding crops were statistically significant and ranged from 705 to 854 kg ha^{-1}. These differences were due to variation in their dry matter. It was concluded that cereal legume sequenced cropping system gave overall higher yield of the cropping system. Inclusion of tropical forage legumes into the current cereal based farming system of Pothwar would not only increase forage availability to the underfed livestock of the area resulting in the increased livestock production but will also improve the N fertility of the soil. Potentially higher production of the subsequent non-leguminous crops will result as residual effect of this improved N status.

Key Words: Forage Legumes; Cropping System; Residual Effects; Dry Matter Yield; Crude Protein Yield; Pakistan.

INTRODUCTION

The increase in population and reduction in productive agricultural land due to urbanization have forced farmers to adopt more intensive cropping system in the rainfed areas of Pothwar. Farmers are growing more and more cereals like sorghum, millet and wheat and are omitting traditional fallow practices. The soils are in general low in fertility and in particular deficient in organic matter. Growing continuous cereal crops has fur-

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ther depleted the soil of nitrogen (Qamar et al., 1999). Application of nitrogenous fertilizers in developing countries like Pakistan is limited due to high cost, problems in getting credit and poor economic conditions of the farmers. Cereal-cereal crop rotation has depleted the soils of important nutrients and organic matter (Hayat et al., 2008).

There are large feed deficits especially of green forage in Pakistan indicating that poor livestock keepers cannot take advantage of the growing market for livestock products to improve their livelihoods. Improvement and integration of forage legumes into crop-livestock systems can improve crops and livestock and make the system more sustainable. Forage legumes provide high-protein fodder for livestock, and improve soil fertility through nitrogen fixation (Anonymous, 2012). After cereals, legumes are the second most important source of human food and animal forage. It is through nitrogen fixation that legumes provide plant tissue that is high in protein. Rhizobia bacteria penetrate the legumes' roots, creating pink nodules that bind nitrogen gas found naturally in the atmosphere. This fixation provides a usable source of nitrogen to the legumes in return for carbohydrates needed by the bacteria (O'Hara, 2001). This mutual interaction between the two species is known as a symbiotic relationship. In agricultural practices, legumes are used as an organic way to amend the soil and reduce crop nutrient deficiency. Mankind has known for millenniums of the importance of legumes environmentally. Legumes help in solublizing insoluble phosphorus in the soil into soluble form available to the plant, improve soil physical characteristics, increase soil microbial activity, restore organic matter and have effective control on weeds (Ghosh et al,. 2007).

The nitrogen-fixing legumes have been used in crop rotations for centuries to reduce soil erosion, improve soil organic matter and physical properties, help reduce pest damage and contribute N to the succeeding crops. Sometimes legumes can be used to supplement perennial pasture, or silage and hay crops (McCartney and Fraser, 2010). Tropical forage legumes may have a potential to improve nitrogen status of the soil and may be preserved as highly nutritious hay or added to maize silage to improve crude protein content. Forage legumes when harvested, leave a substantial quantity of nitrogen into the soil in the form of crop residues and thus have a positive residual effect on the yield of subsequent cereal crops. Rowland et al. (1994) have estimated that significantly higher yields of grain and straw yields of cereals can be expected when grown after legumes in the temperate regions of Australia. Nitrogen is the main limiting factor to the grain and straw yield of the cereal crops after water (Shah et al., 2003). It has been estimated that net benefits of the legumes are often in the range of 50-100kg ha^{-1} of the applied fertilizer (Phoomthaisong et al., 2003). The farmers are facing a shortfall of 30-80 kg N ha^{-1}. With continued cereal cropping, fertilizer N must be supplemented with rotations utilizing legumes break crops to increase supply and availability of nitrogen (Mohd-Radzman et al., 2013).

As there is a persistent energy crisis in the third world countries and fertilizers are going out of the reach of the farmers due to their higher cost, biological nitrogen fixation by legumes has become one of the most attractive strategies for the development of sustainable farming systems. The role of biological nitrogen fixation in legumes is well understood and documented, it has been reported that some species/varieties of legumes are better than others (Okmen et al., 2007). A part of the biologically fixed nitrogen is available to the succeeding non-leguminous crop through decomposition and mineralization of legume residues due to low C:N ratio as compared to cereal residues. Nitrogen benefits in legume cereal cropping sequence have also been attributed to transfer of biologically fixed nitrogen. On the contrary nitrogen benefits are not attributed to the transfer of the fixed nitrogen but to the greater immobilization of nitrate during decomposition of cereal as compared to legume residues (Qamar, 1997). Nitrate sparing is a consistent trait of legumes in rotation systems and may be due to nodulation induces retardation of the legume root growth (Marcellos et al., 1998).

Forage legumes have a great potential as high quality feed and capacity to fix atmospheric nitrogen and can be included into the present cereal – cereal cropping sequence of the Pothwar area for improving soil fertility. Hence it was imperative to investigate their yield potential and their residual effects (Qamar et al., 1999). The present study was conducted to assess the performance of legumes in terms of yield and crude protein content of the five tropical forage like sesbania (*Sesbania aculeata*), cowpeas (*Vigna unguiculata*), rice beans (*Vigna umbellata*), lablab bean (*Lablab purpureus*) and cluster bean (*Cymopsis tetragonoloba*) with reference to a cereal fodder reference crop of millet (*Pennisetum typhoides*) and residual effect of these legumes in comparison to millet on the yield and crude protein of succeeding oats crop in the subtropical subhumid Pothwar plateau of Pakistan under rainfed conditions.

MATERIALS AND METHOD

The study was conducted in the fields of Fodder Programme, Crop Sciences Institute, National Agricultural Research Centre, Islamabad, Pakistan, situated in the subtropical sub humid Pothwar plateau. Soil type was non-calcareous silty clay with pH 7.4. The experiment was laid out in randomized complete block design (RCBD) with three replications. The plot size was $10.8m^2$. Sowing of the experiment was done with a hand pulled drill at a recommended seed rate. The crop was harvested at 50% flowering for legumes and heading stage for millet from each plot for estimation of green fodder yield. One-kg green fodder sample at harvesting time was collected at random for estimating dry matter yield from each plot. The collected sample were weighed, dried in an oven at 100 °C for 48h and up to a constant weight and again weighed to calculate the dry matter yield for each species. Five plants were selected at random in each plot for estimation of plant height. Crude protein was estimated by micro Kjeldahl method (AOAC, 1975). After this trial, boundaries of each plot were clearly demarcated and oats were sown in exactly same plots to find the residual effect on the legumes, if any. The field was ploughed up and was briefly left fallow prior to sowing the following oats crop. The field was again prepared with a cultivator plough (twice) and plank and a high yielding oat variety "Scott" was sown exactly in the same plots with the help of a hand pulled drill with rows placed 30 cm apart. The crop was grown solely under rainfed conditions without fertilizer application. Data on plant height, fresh and dry weight, plant height and crude protein content of oats were collected at heading stage. Data were analyzed statistically using procedure described by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Data on plant height, fresh forage yield, dry matter yield, crude protein content and yield of sesbania (*Sesbania aculeata*), cowpeas (*Vigna unguiculata*), rice beans (*Vigna umbellata*), lablab bean (*Lablab purpureus*) and cluster bean (*Cymopsis tetragonoloba*) along with a cereal fodder reference crop of millet (*Pennisetum typhoides*) revealed highly significant differences (Table 1). Millet was tallest of all the species with a plant height of 174 cm. Among legume species, sesbania was tallest with a plant height of 156 cm followed by cowpeas (112 cm), rice beans (91 cm), lablab bean (84 cm) and cluster bean (54 cm).

There were significant differences among fresh and dry matter yield of forage legumes and millet. The highest fresh matter yield was obtained from millet (22.3 tha^{-1}). Among legume species, sesbania produced the highest fresh matter of 19.2 tha^{-1} followed by cowpeas (17.3 tha^{-1}), rice beans (14.5 tha^{-1}), lablab bean (10.9 tha^{-1}) and least by cluster bean (6.5 tha^{-1}). Dry matter yield almost followed the same pattern. The highest dry matter yield was obtained from millet (8.9 tha^{-1}), followed by cowpeas (4.5 tha^{-1}), sesbania (4.4 tha^{-1}), rice beans (2.9 tha^{-1}), lablab bean (2.2 tha^{-1}) while cluster bean produced lowest dry matter of 1.7 tha^{-1} (Table 1).

There were marked differences regarding crude protein content among all the forage legumes and millet. Cluster bean had the highest crude protein content of 23.2 % followed by cowpea (22.6 %), lablab bean (21.6 %), rice bean (20.1 %) and sesbania

Table 1. Plant height, forage yield and crude protein content of summer forage legumes and millet

Species	Plant height (cm)	Fresh matter yield (tha^{-1})	Dry matter yield (tha^{-1})	Crude protein content (%)	Crude protein yield (kg ha^{-1})
Sesbania	156	19.2	4.4	19.1	843
Cowpeas	112	17.3	4.5	22.6	1007
Rice bean	91	14.5	2.9	20.1	572
Lablab bean	84	10.9	2.2	21.6	474
Cluster bean	54	6.5	1.7	23.2	388
Millet	174	22.3	8.9	6.2	551
LSD	6.8	1.1	0.2	0.6	40.1

(19.1 %). Millet had the lowest crude protein content of 6.2 % which was less than one third of any legume species used in this study (Table 1). Differences of crude protein yield ha^{-1} were significant among all the species except for rice bean and millet where difference was non-significant. Cowpea produced more than 1000 kg ha^{-1} protein followed by sesbania (843 kg ha^{-1}), rice bean (572 kg ha^{-1}), millet (551 kg ha^{-1}), lablab bean (474 kg ha^{-1}) whereas cluster bean produced only 388 kg ha^{-1} of crude protein yield (Table 1).

Data on plant height, fresh forage yield, dry matter yield, crude protein content and yield of oats was significantly higher owing to the previous sesbania and cluster bean (120 cm) and least after millet (111 cm). However, differences in plant height owing to cowpea, rice bean and lablab bean were statistically non-significant (P>0.05). Fresh forage yield and dry matter yield of oats as affected by the previous crops showed marked differences and oats produced significantly (P<0.05) less yield after millet (24.8 t fresh and 7.5 t DMha^{-1}). On the other hand, oats produced highest fresh and dry matter yield owing to the previous legume crop. Oats produced more than 30 tha^{-1} fresh matter when grown after cluster bean and sesbania (Table 2). Dry matter yield of oats owing to the previous crops followed the same pattern. It was least after millet and lablab bean (7.5 tha^{-1}) and ranged from 8.5 to 8.9 tha^{-1} after sesbania, cluster bean and cowpeas. Differences in crude protein content of oats as affected by the previous crops were non-significant and ranged from 9.4% to 9.7%. Differences in crude protein yield of oats as affected by the preceding crops were statistically significant and ranged from 705 to 854 kg ha^{-1}. These differences were due to differences in their dry matter yield (Qamar et al., 1999).

Farmers of the Pothwar region are facing difficult situation to earn their livelihood through rainfed agriculture. They have in general small land holdings and limited resources to maximize their crop production through expensive chemical inputs. Mono crop cereal production has deteriorated soil fertility and organic matter. Potentially productive soils

Table 2. Plant height, forage yield and crude protein content of oats owing to preceding summer forage legumes and millet

Previous Crops	Plant height (cm)	Fresh matter yield (tha^{-1})	Dry matter yield (tha^{-1})	Crude protein content (%)	Crude protein yield (kg ha^{1})
Sesbania	120	33.8	8.9	9.6	854
Cowpeas	114	31.6	8.7	9.5	827
Rice bean	112	29.5	7.8	9.5	741
Lablab bean	110	27.9	7.5	9.6	720
Cluster bean	120	34.0	8.5	9.7	825
Millet	111	24.8	7.5	9.4	705
LSD	8.8	2.6	0.6	0.3	45.8

are going out of cultivation due to rapid soil erosion (ABAD, 1987). Although sufficient forage resources are available in certain parts of the year, they face acute feed deficit during May-June and October-November (Mohammad, 1989). The results of the present study suggest that if the present farming system of the region is changed to include tropical forage legumes over some area during *kharif*, it will have beneficial effects on overall production, productivity and economics. Introduction of tropical forage legumes will not only increase quality and overall availability of forage but will also improve the sustainability of the system. These legumes may be converted into high quality hay for the feed deficit period of October and November.

Results indicate that beneficial residual effects owing to the tropical forage legumes on the subsequent oats crop will produce more fodder oat during winter that can be converted into hay or silage for May and June (Table 2). Forage legumes when harvested leave substantial amount of nitrogen into the soil as crop residues (Jabbar et al., 2010). However, there are several factors which affect biological nitrogen fixation and transfer this biologically fixed nitrogen to the subsequent non-leguminous crop. These vary from crop, site, season and cropping sequence (Peoples et al., 2009).

It is concluded that cereal legume sequenced cropping system gave overall higher yield of the cropping system. Inclusion of tropical forage legumes into the current cereal based farming system of Pothwar will not only increase forage availability to the underfed livestock of the area resulting in the increased livestock production but will also improve the N fertility of the soil. Potentially higher production of the subsequent non-leguminous crops will result as residual effect of this improved N status. However, it is suggested that long-term comprehensive trials on cereal legume rotations on farmer's field may be carried out to get comprehensive data before final recommendations are made to the farmers.

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