Yield parameters and N-uptake of wheat under different fertility levels in legume rotation

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Organic matter obtained from legumes or crop residues improve in the crop rotation and soil structure and water retention capacity. It is the key component of soil which influences plant growth through its effects on the physical, chemical and biological properties of soil by ensuring the sustainability and profitability of agricultural farming. The investigations were carried through a series of experiments in two years at Sindh Agriculture University, Tandojam, Pakistan to confirm the results which consisted two cropping sequences: C_1= crop sown before legume (soybean) and C_2= crop sown after legume with application of three fertilizer levels. Results showed that wheat planted after legume produced better biological yield (6470.33 kg ha^{-1}), maximum harvest index (42.14%), satisfactory grain yield (2763.33 kg ha^{-1}) and higher N-uptake (119.26 kg ha^{-1}). The increased levels of fertilizer at 150-50 NP kg ha^{-1} progressively increased biological yield (7235.50 kg ha^{-1}), harvest index (44.18%), grain yield (3198.19 kg ha^{-1}) and N-uptake (114.01 kg ha^{-1}). It is recommended that nitrogen fertilizer is essential nutrient for achieving satisfactory crop yields. The increased soil productivity and fertility for crop production could be obtained by the inclusion of leguminous crop at least once in a two year cropping sequence, because leguminous crops enrich soil fertility by fixing environmental nitrogen in their root nodules, which in turn supply residual food nutrients to the succeeding crop.

Key words: crop sequences, fertilizers, legumes, N-uptake, wheat

Introduction

Crop rotation is an integral part of the crop production system. A well-planned cropping sequence will reduce insect, pest, disease, ameliorate soil structure, improve organic matter levels, prevents proliferation of weeds and consequently increase the crop yield. The general purposes of rotations are to improve or maintain soil fertility, reduce erosion, reduce the risk of weather damage, reduce reliance on agricultural chemicals and increase net profits (Liebman and Davis, 2000; Bauman *et al*., 2000). The planned rotation

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sequence may be done for two or three years or longer period which exhibit the beneficial effects e.g. improved soil physical, chemical and biological quality, improved energy conservation and timeliness of land preparation and better water conservation (Cooper, 1999; Rochester *et al*., 2001; Hulugalle and Daniells, 2005).

Legumes in the rotation are used to increase the available soil nitrogen because legumes are a large, diverse and agriculturally important family of plants (Heywood, 1971). The benefits of the legumes in cropping systems are well established. Peoples and Craswell (1992); Giller (2001) observed that legumes can fix substantial amounts of atmospheric N_2, which allows them to be grown in N-impoverished soils without fertilizer or N inputs. The most important legume species belong to a small group of herbaceous crop and forage species. The main trait common to these legumes is the ability to fix atmospheric nitrogen and convert it to a useable form for plant growth (Allen and Allen, 1981). The fixed nitrogen leads to a higher protein concentration in its various plant parts which in turn enhances diet and can also be recycled into the environment as a form of fertilizer. Today, forage legume species are assigned different roles in grassland farming depending on their plant structures and abilities (Heath *et al.,* 1985; Ball *et al.,* 1993). From this, one sees that low growing, stoloniferous, and competitive species such as white clover (*Trifolium repens* L.) are used as a component of grazed pasture while high yielding, upright species such as alfalfa (*Medicago sativa* L.) are the best suited to produce hay and silage in a mono-cropping system (Blaser *et al.,* 1973).

The greatest benefit from crop rotation comes when crops grown in sequence are genetically different species such as forage, grasses, cereals and dicot species such as soybeans, white beans, alfalfa and canola which are examples of broadleaf crops that build up soil structure and increase profit potential. Despite these advantages, farmers prefer to remove crop residues off the field to feed livestock or use them as fuel or as building materials. On the other hand, in sustainable farming systems, crop rotation and crop residues have been utilized by the farmers to maintain or improve the level of soil organic matter. To keep the soil productive and sustainable one have to continuously replenish soil organic matter through including legumes in crop rotations and retaining crop residues. With much of the cropping in less developed countries, the above-ground residues are removed with the grain to be used as animal feed or cooking fuel (Wani *et al*., 1995 and Giller, 2001). The residues, depending on type and quality, commonly contain 20-80 kg N ha^{-1} and, in some instances, 150 kg N ha^{-1} (Giller, 2001). Crop rotations have fallen somewhat into disfavor because they require additional planning and management skills, increasing the complexity of farming. A shift away from livestock programs in most parts of North Dakota has also reduced the need for pasture and hay crops and eliminated some rotational crops such as alfalfa from many farms. Solid seeded crops such as small grains and flax have predominated in the past, but row crops such as sunflower, bean, corn and soybean that provides additional planting options and more reasons for crop rotations. One immediate economic benefit of crop rotations is improved yields. For example, sunflower yields over eight years at Crookston, Minnesota were often significantly greater in rotation with other crops than when continuous sunflower was grown (Robinson *et al.,* 1979). Wheat yields were also greater with rotation than continuous wheat in an eight-year study (Miller and Steve, 1984). Experiment at the Agriculture Research Service, Mandan has shown to increase in hard red spring wheat yields that can be expected when an alternative crop is included in the rotation (Tanaka *et al*., 1998). Thus, the systems that incorporate the cultivation of leguminous or oil-yielding crops should be developed for sustainable crop productivity (Sharif *et al.,* 2002; Tarafdar and Claassen, 2003). Crop rotation system, based on periods of bare fallow, has been considered to provide a mean of keeping weeds under control. Field trials that compared the yields of spring wheat produced in crop rotations using bare fallow with yields obtained in crop rotations that did not include periods of bare fallow. It is indicated that the practice of using bare fallow appeared to result in lower yields. It is argued that a system of land use involving periods of bare fallow is unsustainable because fallow is a destructive element in land use, contributing to wind, water and biological erosion of soil. There is also significant evidence that bare fallow contributes to the loss of organic matter from soil. Reducing areas of bare fallow has also been found to be economically justified (Sule and Menov, 2004).

Organic matter has a physical function that it promotes good soil structure, there by improving tilth, aeration and moisture movement and retention (Prochazkova *et al* 2003 and Ingle *et al* 2004). Its chemical function is manifested by its ability to interact with metals, metal oxides, hydroxides and clay mineral to form metal organic complexes and act as ion exchange and store house of N, P and S. Soil organic matter has a biological function in that it provides carbon as energy source to N-fixing bacteria, enhances plant growth root initiation facilitating nutrient uptake, improving chlorophyll synthesis and seed germination (Allen and Allen, 1981). Research studies have shown that regular and proper addition of organic materials (crop residues) are very important for maintaining the tilth, fertility and productivity of agriculture and controlling wind and water erosion more than 50 percent, and preventing nutrients losses by run-off and leaching (Maurya and Lal, 1981; Weiser, *et al*., 1985 and Bukert *et al*., 2000). The expected reduction in soil erosion would be occurred even greater on steeper slopes (Paterson, 2003).

Among the plant nutrients, nitrogen plays a very important role in crop productivity (Ahmad, 1998; Ahmad, 2000) and its deficiency is one of the major yield limiting factors for cereal production (McDonald, 1989 and Shah *et al*., 2003). With continuous cereal cropping systems the N supplied from the decomposition of organic matter must be supplemented from other sources (Strong *et al*., 1986, Herridge and Doyle, 1988 and McDonald, 1992). In most developed countries, adequate N is supplied as chemical fertilizer; however, in majority of the developing countries including Pakistan, this is not possible due to high cost of fertilizers, low per capita income and limited credit facilities available to most farmers. As a consequence, farmer either uses the available organic sources or the crop remains un-fertilized (Herridge *et al*., 1995). To satisfy the required level of plant nutrients, farmers in Pakistan are indispensably inclined to use commercial fertilizers. During the last few years, the price of fertilizers in most developing countries, including Pakistan has reached unprecedented highs whilst supply has been limited when it is needed the most ones (Shah *et al*., 1995).This is resulted in a failure to achieve target yields. Considering the beneficial impact of legumes responsible for biological nitrogen fixation on succeeding crops an experiment was conducted to study the contribution of legumes in the cropping sequences for growth and N-uptake of wheat crop.

Materials and methods

A 2-year field experiment was conducted on wheat at Students Farm, Department of Agronomy, Sindh Agriculture University, Tandojam, Pakistan (25^0-40'N, 68^0-43'E, altitude 19.5 m asl) on clay loam, non-saline, slightly alkaline (pH= 8.1-8.3), low in organic matter (0.58-0.54%) and poor in available phosphorus (3.00-3.50 mg kg^{-1}).

The experiment was conducted as a factorial experiment in randomized complete block design with three replications. The treatments consisted of two cropping sequences [C_1= crop grown before legume and C_2= crop grown after legume (soybean)] and three fertility levels (50-50, 100-50 and 150-50 NP Kg ha^{-1}). The wheat (cv TJ-83) was sown before legume (soybean) and after legume. Urea and Di ammonium phosphate (DAP) were used as the source of nitrogen and phosphorus, respectively. All the phosphorus and half of the nitrogen was applied at the time and the remaining nitrogen was split applied during booting and milky stages. However, in case of legumes, the recommended NP fertilizers were applied. The crop was kept free of weeds. Plant protection measures were adopted when ever necessary. The *biological* *yield (kg ha^{-1})* was obtained by harvested the crop at maturity, sun dried for a week and then weighed with the help of spring balance to determine the total biomass. *Harvest index (%)* was calculated as: economic yield (grain yield)/ biological yield x 100. *The N- uptake in (kg ha^{-1})* was determined by: total dry matter x N in $plant^{-1}$ x 100. Data were statistically analyzed for each year and combined for 2 years by M STAT C software (Stat *et al.*, 1989). Means were separated by Duncan's Multiple Range Test at $p \leq 5\%$.

Results and discussion

Biological yield

The increasing rate of nitrogen significantly increased biological yield in both the years. The higher biological yield (7235.50 kg ha^{-1}) was achieved with the application of 150-50 NP kg ha^{-1}. In different crop sequences the biological yield was maximum (6470.33 kg ha^{-1}) when wheat planted after legume crop during Year-1 as compared to wheat grown before legume during Year-2 (5774.00 kg ha^{-1}) (Table 1). Biological yield (Kg ha^{-1}) increased with every successive increase in the rate of nitrogen fertilizer. Maximum biological yield was achieved in the treatments where 150 kg nitrogen was applied. Increased rates of nitrogen induced vigorous vegetative growth, which in turn resulted in increased biological yield. Crop sequence with preceding crop as soybean had additional benefit of residual fertility from the proceeding leguminous crop, which when utilized in addition to the applied inorganic nitrogen and resulted exuberant crop growth, which ultimately resulted in increased biological yield. Results are in confirmation with results of Nehra *et al.* (2001) that nitrogen is a nutrient which enhances vegetative growth of the crop and have positive relationship with biological yield.

Harvest index

The higher nitrogen rate significantly increased the harvest index in both the years. The application of 150-50 NP kg ha^{-1} produced more harvest index (44.18%). The harvest index was also found more (42.14%) when wheat grown after legume crop as compared to wheat grown before legume (Table 2). There was linear increase in harvest index with each increment in the rate of nitrogen. Minimum harvest index was obtained in the treatments where 50 kg N ha^{-1} was applied, whereas, equally higher harvest index was recorded in the treatment with 100 and 150 kg N ha^{-1}. Nehra *et al.* (2001) have confirmed the results.

Table 1. Biological yield of wheat as affected by fertilizer levels and crop sequences.

Fertilizer Levels NP (Kg ha$^{-1)}$	YEARS (Y)				Average
	Year-1		Year-2		
	Crop sequence (C)				
	C_1 (Before Legume)	C_2 (After legume)	C_1 (Before Legume)	C_2 (After legume)	
50 – 50	4442.00	4860.00	4052.00	4750.00	4526.00
100 – 50	6480.00	7129.00	6340.00	6810.00	6689.80
150 – 50	7350.00	7422.00	6930.00	7240.00	7235.50
Average	6090.67	6470.33	5774.00	6266.67	

C.V. = 3.37%

This behavior can be interpreted in the terms that the lowest level of nitrogen application produced the lowest harvest index, but response of harvest index jumped upto the level of 100 kg N ha^{-1}, thereafter, there was no any noted worthy increasing in harvest index. The response of crop sequences to the harvest index has also been found highly significant. Maximum harvest index has been achieved in the crops which were grown after the legumes in both the years. This may be because of increased rate of photosynthesis due to the utilization of an additional fertility from residual of the leguminous which in turn resulted in heavier grains, thereby increasing the harvest index.

Grain yield

The application of nitrogen linearly increased the grain yield of wheat crop and maximum response (3198.19 kg ha^{-1}) was exhibited with incorporation of 150-50 NP kg ha^{-1} produced higher grain yield. Among the crop sequences, higher grain yield (2763.33 kg ha^{-1}) was obtained when the wheat planted after legume crop whereas, wheat sown before legume recorded minimum grain yield (1390.00 kg ha^{-1}) (Table 3). The maximum grain yield kg ha^{-1} was produced from the plots, where 150 kg N ha^{-1} was applied. Results are supported by Hussain and Shah (2002) who also were in the view that N significantly increased grain yield of wheat. Results are demonstrated in accordance with Bazitov (2000) and Bhagat *et al.* (2001) that more number of tillers plant^{-1}, longer spikes, more number of spikelets spike^{-1} and greater number of fertile florets resulted in maximum number of grain filled thus, all collectively resulted into increased grains yields ha^{-1}. The results further showed significant effect of crop sequences for the grain yield. Higher grain yields were achieved in both the years in the crop sequences which included leguminous (soybean) as preceding crop. This may also be due to the process of symbiosis in legumes where mutual contact between rhizobium bacteria and the leguminous crop occur and roots fix atmospheric nitrogen in the nodules which supply nitrogen to the succeeding. The results are in accordance with the results obtained by Ghosh *et al.* (2000) and Rusu *et al.* (2001) that legume growing in the crop sequence produce sufficient nitrogen and reduce the rate of in-organic nitrogen.

Table 2. Harvest index (%) of wheat as affected by fertilizer levels and crop sequences.

Fertilizer Levels NP (Kg ha^{-1})	YEARS(Y)				Average
	Year-1		Year-2		
	Crop sequence (C)				
	C_1(Before Legume)	C_2(After legume)	$C_{1(}$Before Legume)	$C_{2(}$After legume)	
50 – 50	35.00	38.00	34.30	37.50	36.20
100 – 50	43.50	43.60	43.40	43.50	43.50
150 – 50	43.70	44.83	43.40	44.80	44.18
Average	40.73	42.14	40.37	41.93	--

C.V. = 4.99%

N-uptake in wheat.

The increasing rate of nitrogen also increased N uptake in both the years. The application of 150-50 NP kg ha^{-1} resulted higher N uptake (114.01 kg ha^{-1}). In different crop sequences the N uptake was maximum (119.26 kg ha^{-1}) when wheat was planted after legume during year-1. It is clearly evident from the data that N uptake increased due to previous legume crop. It was further observed the N levels increased from 50 to 150 kg ha^{-1}, the N uptake also increased from 69.88 to 114. 01 kg ha^{-1} (Table 4). As per statement of Kubat *et al.* (2003) that both the organic and mineral fertilization enhanced significantly the N-uptake by the cultivated crops. The effect of nitrogen input was the highest with the alternate cropping indicating that it was more demanding for the external N-input. They further reported that with continuous planting the soil structure degraded. Rawat and Pareek (2003) also supported the finding of the study by concluding that the N uptake of the crop also increased with increasing rates of N.

Table 3. Grain yield of wheat as affected by fertilizer levels and crop sequences.

Fertilizer Levels NP (Kg ha^{-1})	YEARS (Y)				Average
	Year-1		Year-2		
	Crop sequence (C)				
	C_1(Before Legume)	C_2(After legume)	C_{1}(Before Legume)	C_{2}(After legume)	
50 – 50	1554.00	1850.00	1390.00	1780.00	1643.50
100 – 50	2821.00	3110.00	2750.00	2960.00	2910.25
150 – 50	3208.75	3330.00	3010.00	3244.00	3198.19
Average	2527.92	2763.33	2383.33	2661.33	--

C.V. %= 8.04

Conclusions

The overall results of the present investigations conclude that nitrogen fertilizer is essential nutrient for achieving satisfactory crop yields. The increased soil productivity and fertility for crop production could be obtained by the inclusion of leguminous crop at least once in a two year cropping sequence, because leguminous crops enrich soil fertility by fixing environmental nitrogen in their root nodules, which in turn supply residual food nutrients to the succeeding crop.

Table 4. N-uptake in wheat plant as affected by fertilizer levels and crop sequences.

Fertilizer Levels NP (Kg ha^{-1})	Y E A R S (Y)				Average
	Year-1		Year-2		
	Crop sequence (C)				
	C_1(Before Legume)	C_2(After legume)	C_{1}(Before Legume)	C_{2}(After legume)	
50 – 50	51.08	97.78	53.16	77.52	69.88
100 – 50	10.95	131.17	100.42	108.96	111.56
150 – 50	115.24	120.84	106.44	113.52	114.01
Average	90.69	119.26	86.67	100.00	---

Recommendations

Continuous cropping in the sequence of wheat-cotton be avoided. Higher yields of wheat could be achieved in the farming system which includes legumes in crop rotation. The application of 150-50 NP kg ha^{-1} is sufficient for satisfactory yields of wheat crop. The use of in-organic nitrogenous fertilizers could be minimized by growing legume crops. It is suggested that there are opportunities to integrate appropriate legume-based technologies into the farming systems based on an identification of inherent nitrogen-release patterns.

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