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Impacts of Fertilization Systems on Nitrogen Loss and Yield of Oilseed Rape (*Brassica napus* L.)

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Abstract: Farmyard manure is considered as a source of plant nutrient supply, but high N loss and low N use efficiency are often serious challenges facing this source of nutrient. It is supposed that a combination of manure with inorganic fertilizers can reduce this problem. A two year experiment was conducted in 2004-2005 at Mazandran province of Iran in order to study the effects of manure, inorganic nitrogen and combination of manure-inorganic nitrogen on N loss and yield of winter oilseed rape (*Brassica napus* L.) under rainfed conditions. Treatments included 0, 50, 100 and 150 kg N ha^{-1} urea (F_0, F_{50}, F_{100}, F_{150}), 100 kg N ha^{-1} urea + 50 kg N ha^{-1} manure ($F_{100}M_{50}$), 50 kg N ha^{-1} urea + 100 kg N ha^{-1} manure ($F_{50}M_{100}$), 150 kg N ha^{-1} manure (M_{150}). The highest grain yield (3 ton ha^{-1}) was obtained with the 150 kg N ha^{-1} as urea treatment in both years. Grain yield in M_{150} treatment was significantly lower ($p<0.05$) than F_{150}. However $F_{100}M_{50}$ and $F_{50}M_{100}$ resulted in similar yields compared with F_{150} treatment. Results also showed that $F_{100}M_{50}$ and $F_{50}M_{100}$ treatments decreased N loss (4 and 3 kg N ha^{-1} $year^{-1}$, respectively) compared to application of manure alone (33.5 kg N ha^{-1} $year^{-1}$) and F_{150} (36 kg N ha^{-1} $year^{-1}$). Overall, it could be conducted that $F_{100}M_{50}$ is the best treatment because it produced similar grain yield compared to F_{150} while resulted in lower N loss as well.

Key words: Cattle manure, N loss, winter oilseed rape, integrated nitrogen management, nitrogen, organic input

INTRODUCTION

The negative environmental impacts of high N loss from agricultural systems and the high amount of fossil fuels involved in the industrial fixation of N for fertilization, necessitate better understanding of the connection between management practices and the N loss. This impetus has led to comparison research examining the N cycle of varying fertilization systems with an aim to isolate the managements which can decrease leakage of N from the system and to evaluate inputs on their ability to be retained in the crop or soil (Kramer *et al.*, 2002). The effects of an integrated nutrition system; i.e., manure + inorganic fertilization on nitrogen loss have been rarely studied while the separate effects of them have been investigated in many experiments. Bergstrom and Kirchmann (1999) and Basso and Ritchie (2005) reported more N loss in the manure treated plots compared with plots treated by inorganic N. Thomsen (2005) showed that application of manure in fall and spring caused 21 and 13% NO_3 leaching, respectively. Brrouwer and Powell (1998) also reported high N loss from cattle manure (90 kg ha^{-1} $year^{-1}$). In contrast, Eghball (2002) and Sims (1987) reported more NO_3 leaching at inorganic fertilization systems compared to beef cattle manure and poultry manure treatment. Poudel *et al.* (2001) found that compared to the conventional system, cumulative N loss for the organic and low-input systems were lower by 80 and 92%, respectively.

In addition to the role of organic fertilizers on decreasing N loss, they are of great interest to most farmers since they are simply available as a source of multiple nutrients and can improve soil characteristics to much extent. Information on the effects of organic and integrated fertilization systems on grain yield of winter oilseed rape is sparse (Rathke *et al.*, 2006). Based on data given by Rathke *et al.* (2005), slurry application reduced the yield of winter oilseed rape between 7.8 and 16.6% compared to inorganic fertilizers. Application of farmyard manure + poultry manure + sugarcane filter cake as a substitute for chemical fertilizers resulted in lower grain than full chemical NPK in cotton (Khaliq *et al.*, 2006). In contrast, Eghball and Power (1999a) showed that cattle manure application resulted in similar corn grain yield as that for chemical fertilizer treatment in all years of experiment except for no-till in 1996. It is supposed that a

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combination of manure and chemical fertilizer as source of crop N demand may be able to produce higher yield compared with application of manure or chemical fertilizer alone which is in part due to temporally distinct patterns of N release from the two sources (Prasad *et al*., 2002; Ghosh *et al*., 2004).

Very little information exist on the application of manure and manure + inorganic fertilization as a source of N to meet oilseed rape demand especially under sub-humid environments. The objective of this experiment was to assess the effects of inorganic fertilization, beef cattle feedlot manure and manure-inorganic fertilizer combination on N loss and oilseed rape yield.

MATERIALS AND METHODS

Experimental site: A two year experiment was conducted in 2004 and 2005 at Research Station of Shahid Beheshti University at Savad khooh (36.4° N and 53.1° E, Elevation 1200 m) in Mazandran province. Mean annual precipitation was 738 and 712 mm in 2005 and 2006, respectively, of which 540 and 578 mm occurred during growing season (October up to June) of 2004-2005 and 2005-2006, respectively. 50, 37 and 13% of this precipitation happened during fall, winter and spring, respectively of 2004-2005 growth season. These values were 40, 30 and 30% for 2005-2006 growth season. The average of temperature during fall (2004), winter, spring and summer of 2005 was, 14, 8.4, 17.9 and 22.3°C. These values for 2005-2006 were, 16.2, 8.1, 19.8 and 25.2°C.

Before the experiment, the field was under rice cultivation for many years, followed by 5-year fallow. The soil texture was clay loam. Other soil characteristics are shown in Table 1.

Experimental design: The experiment was conducted as a randomized complete block design with four replications. Treatments included 0 (F_0), 50 (F_{50}), 100 (F_{100}), 150 (optimum- F_{150}) kg N ha^{-1}, 100 kg N ha^{-1} urea + 50 kg N ha^{-1} manure ($F_{100}M_{50}$), 50 kg N ha^{-1} urea + 100 kg N ha^{-1} manure ($F_{50}M_{100}$) and 150 kg N ha^{-1} manure (M_{150}). Treatments were located on the same plots site during both years.

Plots were 2.1 m wide (7 rows with a 0.30 m row spacing) by 5 m long. Beef cattle feedlot manure (collected during October 2004 and 2005) was applied to oilseed rape by disking and incorporated into the 15 cm topsoil 2 weeks before planting. Manure application was based on the assumption that 35 and 20% of total N in manure would become available during the first and second years after application, respectively (Eghball and Power, 1999a).

Table 1: Characteristics of soil (0-15 cm) and cattle manure in 2004 and 2005

Source	Moisture (%)	pH	EC (dS m^{-1})	P (ppm)	Total N (g kg^{-1})	OC (g kg^{-1})
Soil		7.8	1.07	8[a]	2.43	23.3
Manure (2004)	40	6.4	7.00	3500[b]	13.70	220.0
Manure (2005)	45	7.0	6.00	4200[b]	15.60	200.0

[a]: Available phosphorus, [b]: Total phosphorus

According to this method, total manure application were 43, 28.6 and 14.6 ton ha^{-1} in M_{150}, $F_{50}M_{100}$ and $F_{100}M_{50}$ treatments, respectively for two years. Half of urea was applied at planting and the remaining was manually side-dressed at the beginning of stem elongation. Oilseed rape cv. Hyola was overseeded on 6 and 16 November 2004 and 2005, respectively and thinned to 66 plants m^{-2} at the three-leaf stage. Plots were kept weed-free during the growing season by hand weeding.

Soil sampling, soil and plant analysis: Initial soil sampling was conducted at the time of plot establishment in October 2004. Subsequent soil sampling was conducted at the end of the experiment in June 2006. Five soil cores (2.5 cm diameter at 30 cm depth) were taken from each plot in each sampling. The soil was mixed thoroughly in a bucket, sieved through a 2 mm-mesh screen and air-dried prior to analysis. Total N was determined by the Kjeldahl digestion, distillation (Bremner, 1996).

Oilseed rape was harvested in May 2005 and 2006 from the 4 m long of the middle five rows. Grain yield was adjusted to 15% water content. Samples were then taken from grain and stem samples to determine N content.

Calculation of N loss: N loss (NO_3 leaching + N_2O and NH_3 emission) was determined based on the calculation of N balance according to the method of Poudel *et al*. (2001). Average annual N loss calculated through N balance minus soil N storage. N balance was determined by the following formula:

$$\text{N balance} = \text{Input N (kg ha}^{-1}) - \text{Output N (kg ha}^{-1})$$

Soil N storage calculated by the following formula:

$$\text{Soil N storage} = [\text{Total N in the end of experiment (g kg}^{-1}) - \text{Total N at the initiation of experiment (g kg}^{-1})] \times \text{bulk density (g cm}^{-3}) \times \text{soil depth (cm)} \times 100]$$

There were no significant differences between the experimental plots with regard to initial soil total N at 0-30 cm depth. So, the average 2.09 g N kg^{-1} soil was accounted as the initial soil N content for all treatments.

Bulk density did not change under different fertilization systems (data have not been shown), so its initiation value (1.3 g cm^{-3}) used for 0-30 cm soil depth, across all treatments.

Statistical analysis: Data were analyzed statistically using PROC GLM procedure in SAS (1996). All parameters were analyzed by one-way method within each year as randomized complete block design. When F-tests showed statistical significance, the Duncan's multiple range test ($p<0.05$) was performed on means for particular comparison.

RESULTS AND DISCUSSION

There was a significant difference between treatments for grain yield (Table 2). Optimum amount of chemical fertilization was 150 kg ha^{-1} (F_{150}) in both years. Grain yield for organic treatment (M_{150}) was significantly ($p<0.05$) lower than F_{150} treatment in both years (Table 2). Stevenson *et al.* (1998) also found that application of cattle manure under certain environmental conditions may not entirely meet the N demands of winter oilseed rape and hence, supplemental chemical N fertilizer may be needed. Pang and letey (2000) noted that due to inadequate N supply from manure, high initial applications may be used to build up the organic pool followed by lower application rates. Beauchamp (1986) also reported that less than 10% of the total N in the solid farmyard manure became available during the year of application, indicating the very slow rate of N release from this source into the soil. Change and Janzen (1996) found that after 20 year of cattle manure application, only 56% of the N content of manure was mineralized, suggesting that insufficient amounts of N were supplied to meet the needs of most annual crops. Mooleki *et al.* (2004) stated that rate in excess of 400 kg N ha^{-1} $year^{-1}$ could be appropriate for the first 3 or 4 year on previously unmanured land to achieve high yield in oilseed rape. This type of plant response to cattle manure could be attributed to the slow release of the organic N from manure, high C:N ratio (exceeding 15:1) and the low inorganic N content (Mooleki *et al.*, 2004).

In contrast to above results, Eghball and Power (1999 a,b) found that cattle manure application in maize, under conventional land preparation resulted in similar grain yield as that for chemical fertilization treatment. This difference can be related to higher N availability of manure in Eghball and Power experiment (1999 a,b) compared with ours. In this experiment, apparent NUE [(total treatment N uptake in 2 year -total check N uptake in 2 year)/N applied in 2 year] × 100, was 22% for manure and 50% for the fertilizer treatment, These values for our experiment was 17 and 58%, respectively (Table 2). These values showed in present study, N availability has been lower than experiment of Eghball and Power (1999 a,b). Lower total N uptake by oilseed rape in the organic treatment compared to the inorganic treatment also verified this assumption (Table 2). C:N of manure in the Eghball and Power (1999 a, b) experiment was approximately similar to that in the present study. Hence, it seem that the difference in climate condition and soil properties were the main reasons for difference in N mineralization (N availability) in manure. Pattern of N uptake by plant can also affect its response to manure application. Winter oilseed rape accumulates 25-30% of total N (40-80 kg N ha^{-1}) from the soil during autumn (Rathke *et al.*, 2006) when N mineralization in manure is expected to be low. In spring when N mineralization from manure increase due to favorable climate condition, winter oilseed rape starts flowering and demand to N decrease (Rathke *et al.*, 2006). Combined treatment $F_{100}M_{50}$ in the first year and $F_{100}M_{50}$ and $F_{50}M_{100}$ treatments in the second year of the experiment, produced similar yield to F_{150} treatment (Table 2). Patra *et al.* (2000) showed that herb and essential oil yields of mint (*Mentha arvensis* cv. Hy 77) were significantly higher in combined application of farmyard manure and inorganic fertilizer compared to that of inorganic fertilizer alone. But, Khaliq *et al.* (2006) observed that combination of 10 ton ha^{-1} organic fertilizer (farmyard manure + poultry manure + sugarcane filter cake) + EM (effective microorganism) and 1/2 mineral NPK yielded very similar to that obtained from full recommended mineral NPK in cotton. Ghosh *et al.* (2004) also found that application of 75% NPK + 5 ton ha^{-1} farmyard manure compared to 100% NPK resulted in equal and more grain yield in sorghum and soybean, respectively. It can be concluded that due to slow release

Table 2: Seed yield and top N uptake of oilseed rape for various fertilization treatments in 2004 and 2005

	Total nitrogen uptake (kg ha^{-1})		Seed yield (kg ha^{-1})	
Treatments[a]	2004	2005	2004	2005
F_0	49[d]	42[e]	1175[e]	1050[d]
F_{50}	61[d]	62[d]	1607[d]	1550[c]
F_{100}	104[c]	101[c]	2265[bc]	2290[b]
F_{150}	135[a]	131[a]	3100[a]	2900[a]
$M_{50}F_{100}$	120[b]	126[ab]	2779[ab]	2813[a]
$M_{100}F_{50}$	110[b]	121[b]	2652[b]	2510[ab]
M_{150}	93[c]	100[c]	2017[c]	2100[b]

[a]: F_0, F_{50}, F_{100} and F_{150} and are 0, 50, 100 and 150 kg N $ha^{-1}year^{-1}$ urea, respectively. $F_{100}M_{50}$ is 100 kg N ha^{-1} urea + 50 kg N ha^{-1} manure, $F_{50}M_{100}$ is 50 kg N ha^{-1} urea + 100 kg N ha^{-1} manure, M_{150} is 150 kg N ha^{-1} manure. The means having the same letter(s) within each year are not significantly different at $p<0.05$ by Duncan Multiple Range Test (DMRT)

Table 3: Cumulative N balance, soil N storage (at 0-30 cm soil depth) and N loss for the manure, inorganic fertilizer and combination of manure- inorganic fertilizer treatments across 2004-2005

Treatments[a]	Input ($kg\ ha^{-1}$)	Output ($kg\ ha^{-1}$)	Balance ($kg\ ha^{-1}$)	Total N ($g\ kg^{-1}$)	Soil N storage ($kg\ N\ ha^{-1}$)	N loss ($kg\ N\ ha^{-1}$)
F_0	0	91	-91	2.06[d]	-100[e]	9[c]
F_{50}	100	123	-23	2.08[cd]	-32[d]	9[c]
F_{100}	200	205	-5	2.08[cd]	-29[d]	24[b]
F_{150}	300	266	34	2.08[cd]	-38[d]	72[a]
$F_{100}M_{50}$	411	246	165	2.13[b]	157[c]	8[c]
$F_{50}M_{100}$	511	231	280	2.16[ab]	274[ab]	6[c]
M_{150}	612	193	419	2.18[a]	352[a]	67[a]

[a]: F_0, F_{50}, F_{100} and F_{150} and are 0, 50, 100 and 150 kg N $ha^{-1}year^{-1}$ urea, respectively. $F_{100}M_{50}$ is 100 kg N ha^{-1} urea + 50 kg N ha^{-1} manure, $F_{50}M_{100}$ is 50 kg N ha^{-1} urea + 100 kg N ha^{-1} manure, M_{150} is 150 kg N ha^{-1} manure, The means having the same letter(s), are not significantly different at $p<0.05$ by DMRT

of nitrogen in manure (Mooleki *et al*., 2004), heavy users of N as cotton, sorghum and oilseed rape at integrated nitrogen management can not produce more yield than inorganic fertilization system in short term, but plant such as soybean and mint with low N demand can.

In spite of less N accumulation in combined treatments (Table 2), similar yield of $F_{100}M_{50}$ and $F_{50}M_{100}$ compared with F_{150} might be due to better synchronization of released N and crop uptake (Qian and Schoenau, 2002) and positive effects of manure on physicochemical and biological properties of soil (Nyamangara *et al*., 2001; Damodar Reddy *et al*., 1999; Kanchikerimath and Singh, 2001).

Amount of N storage in soil and N loss: Soil sampling showed that the organic treatment caused the highest amount of N storage (2.18 g N kg^{-1}) in soil in both years (Table 3). $F_{50}M_{100}$ treatment was ranked second in this respect. Results indicated that the organic treatment added 352 kg N ha^{-1} to soil during both years of experiment, which was 2.24 and 1.28 time more than those of $F_{100}M_{50}$ and $F_{50}M_{100}$, respectively (Table 3). Wander *et al.* (1994) also reported significant differences in total N of soils in animal-based (3.5 g kg^{-1}), cover crop-based (3.42 g kg^{-1}) and conventional (3.25 g kg^{-1}) systems after 10 years of differential management in east-central Pennsylvania.

The average annual N loss which was calculated as the difference between N balance and soil N storage, showed that N loss in $F_{100}M_{50}$ and $F_{50}M_{100}$ treatments were only 4 and 3 kg N ha^{-1} $year^{-1}$, respectively (Table 3). These values were 33.5 and 36 kg N ha^{-1} $year^{-1}$ for complete manure and inorganic fertilizer applications, respectively.

As observed, combined treatments reduced N loss compared to the organic and inorganic treatments (Table 3). However, very little information exist in literature on the effects of integrated nutrition systems (manure + inorganic) on nitrogen loss. Nyamangara *et al.* (2003) reported that combined treatment, 12.5 ton manure ha^{-1} plus 60 kg N ha^{-1} acted as the best in terms of maintaining high dry matter yield in maize and minimizing N leaching. Such a response could be attributed to lower amount of manure application which has resulted in reduction in NO_3 leaching from May to November 2005 when the field was left fallow (Thomsen, 2005). On the other hand, considerable amount of soil N would immediately be immobilized after manure application (Qian and Schoenau, 2002). Under this condition, N availability is less than inorganic fertilizer system especially in autumn and winter, this can also decrease NO_3 leaching.

As observed in Table 3, no significant difference was observed between M_{150} and F_{150} with respect to N loss. Sims (1987) reported that NO_3-N leaching to the 0.6 m depth was greater under mineral N application than poultry manure application. Eghball (2002) also reported that residual soil NO_3 to a depth 1.2 m was greater for inorganic fertilizer than manure and compost treatments in dry year. In contrast, in his study on spring barley, Thomsen (2005) reported that manure application in fall and spring caused 21 and 13% NO_3 leaching, respectively. The observed disagreements could be related to difference rainfall pattern during and off the growing season and C:N ratio of manure (Thomsen, 2005).

CONCLUSION

Grain yield in the organic fertilizer system (M_{150}) was significantly less than inorganic fertilizer system (F_{150}) in both years. Integrated treatments ($F_{50}M_{100}$ and $F_{100}M_{50}$) produced similar yields to that obtained from F_{150} while they resulted in less nitrogen loss. Therefore, it is recommended to reduce the amount of inorganic fertilizer and supplement it with manure to decrease environmental hazards including nitrate leaching. Regarding the high cost of manure, treatment $F_{100}M_{50}$ suggested.

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