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RESPONSE OF BREAD WHEAT TO INCREASING MUSTARD MEAL NITROGEN APPLICATION ON PELLIC VERTISOL AND EUTRIC NITOSOL

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ABSTRACT: Mustard seed meal was evaluated on the field as source of nitrogen for bread wheat on Pellic Vertisol and Eutric Nitosol in a split plot design with three replications. Highly significant yield increases were obtained due to mustard meal nitrogen rates during all the experimental periods on the Vertisol. The increase in the grain yields of wheat was linearly related to the mustard meal nitrogen rates ($r=0.98$ and 0.96 for fresh and decayed meal, respectively) and varied from two to ten fold of the control. On the Nitosol, significant effect was obtained only in one crop season. Greenhouse experiment on the nitrogen uptake from the mustard meal using ^{15}N showed significant difference on both soil types. On the Vertisol the per cent nitrogen derived from the meal and per cent nitrogen use efficiency varied from 18 to 40 and from 18 to 62%, respectively. On the Nitosol, these values varied from 25 to 71 and from 43 to 62%, respectively. Application and incorporation of the mustard seed meal into the soil 20–25 days before planting minimised the toxicity of the meal on seed germination and seedling growth.

Key words/phrases: Eutric Nitosol, mustard seed meal, nitrogen use efficiency, Pellic Vertisol, wheat

INTRODUCTION

In many soils nitrogen is the most limiting nutrient element for crop production. Inorganic nitrogenous fertilizers, apart from being expensive and needed in large quantities by plants, undergo various transformations, which result in losses from the soil and therefore unavailability to plants. Moreover chemical nitrogenous fertilizers may be transformed in the soil to nitrous oxide, which is one of the greenhouse gases responsible for global warming (Gupto *et al.*, 1988) and may be leached as nitrate and pollute ground water. Such problems and limitations associated with the use of chemical fertilizers therefore make natural sources of nitrogen important alternatives.

Various organic sources of plant nutrients such as by-products or wastes from processing animal and plant products contain several per cent of nitrogen and phosphorus and can be used as organic fertilizers (Cooke, 1982; Sharama and Deb, 1988). Organic fertilizers besides acting as good sources of plant nutrients also improve the physical condition of the soil. Moreover, organic fertilizers have some very important merits that are not common in inorganic fertilizers. Some of these include: slow release of nutrients at a rate that matches the uptake of crops; the possibility of application at a higher rate without the risk of damage to crops; the possibility to tie up mineralised nitrogen thus preventing its loss by denitrification, volatilisation or leaching (Larson *et al.*, 1972; Cooke, 1982; Gupto *et al.*, 1988; Huc, 1988; Sharama and Deb, 1988). Organic sources of plant nutrients are not also without drawbacks such as: their dependence on environmental factors like soil type, temperature, aeration and moisture to release nutrients, especially nitrogen. The low and unbalanced nutrient composition and the expenses associated with transportation and application are also other drawbacks (Mengel and Kirkby, 1978; Lindemann *et al.*, 1988).

In Ethiopia edible oil is extracted, among others, from mustard seed (*Brassica carinata* (L)). Mustard seed meal, the by-product which constitutes about 70% of the initial material, is rich in organic nitrogen (5.8–6.1% N or over 30% crude protein). It also has good content of phosphorus (0.87–0.93%), potassium (0.84–0.97%) and other essential plant nutrients such as calcium, magnesium, sodium, sulphur and organic carbon. Unlike niger, ground nut, safflower or cotton seed meal, mustard seed meal is not used directly as a source of energy and protein for livestock due to its high content of thioglucoside compounds known as glucosinolates. These substances can be hydrolysed by the myrosinase enzyme (present endogenously in *Brassica* tissues) to release a range of hydrolysis products including oxazolidinethiones, nitriles, thiocyanates and various forms of volatile isothiocyanates. The last mentioned compound and its secondary products are particularly toxic to germinating seeds and seedlings and animals. In the latter they cause, for example, goitre in non-ruminants (Joseffson, 1970; Kirkegaard *et al.*, 1994; 1995; 1996; 1998; Sarwar *et al.*, 1998). Due to these bottlenecks there is a lack of useful disposal of this by-product.

The potential use of mustard seed meal as protein supplement in diet of sheep had been established previously (Teshome Shenkoru and Goshu Mekonnen, 1990). However, considering the current large area under mustard seed production (Teshome Shenkoru and Goshu Mekonnen, 1990) and its potential expansion, it is still important to find other alternative uses of mustard seed meal. The objectives of this study were, therefore, to determine the value of mustard meal as a source of nitrogen fertilizer for bread wheat on Eutric Nitosol and Pellic Vertisol under field conditions and to determine the nitrogen uptake by wheat under greenhouse condition with the help of ^{15}N.

MATERIALS AND METHODS

Field experiment

The field experiments were conducted for three seasons at Holetta Research Centre and Ginchi sub-centre of the Ethiopian Agricultural Research Organization. The soils of Holetta and Ginchi are classified as Eutric Nitosol and Pellic Vertisol, respectively (Provisional Soil Map of Ethiopia, 1986). Table 1 shows the climate of the two centres during the experimental period. The Experimental design was a split plot with three replications, where the main plots consisted of condition of the mustard seed meal, viz., decayed mustard seed meal and fresh mustard seed meal, whereas the sub-plots consisted of four levels of nitrogen derived from mustard meal *i.e.*, 0, 60, 90, 120 and 180 kg N ha^{-1}. In terms of fresh mustard meal weight it was 0.98, 1.47, 1.97 and 2.95 t ha^{-1}, whereas for the decayed mustard seed meal these values were 1.36, 2.05, 2.73 and 4.09 t ha^{-1}. The recommended rate of phosphorus for wheat both on Vertisols and Nitosols was 26 P kg ha^{-1}. As the fresh and decayed mustard seed meal contains 0.93 and 0.87% P, it was only after the consideration of the total phosphorus in the meal that the difference was applied as triple super-phosphate. Composite soil samples were collected from the experimental fields from 0–20 cm soil depth before mustard meal application to characterize the chemical and physical properties of the soils (Table 2). To avoid toxicity of the mustard seed meal on seed germination, the application and incorporation of the mustard seed meal with the soil was done 15–20 days before planting. The time of mustard meal application was based on the result of an observation trial carried out under greenhouse condition at Holetta Research Centre. The application and incorporation of the meal was done manually. At the recommended planting time bread wheat variety ET-13 with seed rate of 100 kg ha^{-1} was planted in 6 m^2 plots containing ten rows and 20 cm spacing and 1 m between plots. Phosphorus was applied in rows to the treatments that received additional triple super-phosphate. Planting was done manually. Three to four hand weeding was done at both locations during the growth period. At physiological maturity entire plots were harvested and threshed manually. Rape-seed and wheat was sown without fertilizer application as a following crop to see the residual effect of mustard meal application at Holetta and Ginchi, respectively.

Table 1. Climate of the Holetta/Ginchi (H/G) Agricultural Research Centre during the experimental period (1991/92, 1992/93 and 1993/94).

Parameter	June H/G	July H/G	August H/G	September H/G	October H/G
Mean monthly rainfall	89.9/109.6	232.1/199.5	229.0/287.6	172.5/146.5	2.6/1.7
(mm)	115.4/131.6	190.9/221.1	312.6/213.6	112.1/90.6	35.3/78.5
	103.1/161.2	218.1/121.9	278.1/314.1	214.3/192.7	27.4/53.6
Mean monthly max.	23.8/24.1	19.5/20.6	19.8/21.0	20.9/22.3	22.2/23.5
temp. (°C)	22.5/23.8	19.4/20.4	18.6/19.7	19.7/21.6	20.9/22.6
	21.6/23.6	19.6/21.6	19.4/21.6	19.4/22.2	21.5/23.6
Mean monthly min.	8.5/11.6	10.2/11.5	10.0/11.2	7.9/10.1	3.4/5.8
temp. (°C)	8.9/8.8	9.0/9.2	10.5/9.8	7.5/8.0	5.9/6.6
	8.3/11.2	9.1/11.4	8.6/11.4	7.7/10.6	5.7/9.6

Greenhouse experiment

The N-uptake experiment was carried out under greenhouse condition at Holetta Research Centre. The soils (Pellic Vertisol and Eutric Nitosol) were collected from 0–20 cm depth of the fields on which the field experiments were conducted. The soils were dried, ground and filled in 3-kg capacity pots. The treatments consisted of five nitrogen rates from fresh mustard meal viz. 10, 20, 30, 40 and 60 mg N kg^{-1} soil. In all of the mustard meal nitrogen treatments 3 mg N kg^{-1} soil of 10% ^{15}N a. e of ammonium sulphate was included for labelling purpose. The soil moisture of the experiment was subjected to 60% field moisture capacity by watering two times a day during the first three months of plant growth. The amount of water applied to each pot was determined by weight. After the 3rd month the moisture of the soil was reduced to 30-40% field moisture capacity so as to bring nearer to the field moisture capacity which is usually observed at the late growth stages. At this stage it was difficult to determine the volume of water to be applied by weight because of the difference in the growth performance of the plants in each pot. Hence equal amount of water was applied to the pots with the same soil type taking into account the pots with profuse plant growth to which additional volume of water was applied.

Table 2. The major physico-chemical characteristics of the experimental soils.

Type of soil	pH 1:1 H_2O	N %	P ppm	OC %	Particle size			Exchangeable cations Meq $100g^{-1}$ soil.				CEC	Exch. base	ESP	C:N
					Clay	Silt	San	Na	K	Ca	Mg				
Nitosol	5.0	0.18	7.82	1.95	65.75	23.75	10.50	0.11	1.5	2.57	7.82	23.6	12.0	0.95	11
Vertisol	6.5	0.11	9.85	1.31	63.90	22.35	13.75	0.80	3.9	14.2	47.6	53.3	66.6	1.20	12

The greenhouse was damaged by wind when the plants on the Nitosol and Vertisol were at late grain filling and heading stages, respectively. Hence to avoid bird damage the plants on Eutric Nitosol were harvested at grain filling stage. On the Pellic Vertisol the plants were harvested at physiological maturity. The plants were dried at 70° C for 70 hrs and processed for total nitrogen content determination by Kjeldal method and %^{15}N analysis by Emission Spectrometry at IAEA laboratories at Seibersdorf, Austria.

The per cent nitrogen derived from the mustard meal (% Ndf mm) was calculated following (IAEA, 1990; Rao *et al.*, 1992) by using the equation:

% Ndf mm = 1 - (%^{15}N a. e in plants in pots with mustard meal / %^{15}N a. e in plants in pots without mustard meal) x 100.

The % mustard meal nitrogen use efficiency (% mm NUE) was calculated as:

% mm NUE = Mustard meal nitrogen yield in crop/mustard meal nitrogen applied x 100.

Mustard meal nitrogen yield = % Ndf mm x total nitrogen yield.

Mustard meal analysis

The fresh and decayed mustard meal samples were analyzed for phosphorus, potassium, calcium, magnesium, sodium, sulphur and organic carbon at Holetta Research Centre (Table 3). Total nitrogen content was analyzed both at Holetta and IAEA laboratory, Seibersdorf, Austria by Kjeldal method; per cent phosphorus by dry ashing $MgNO_3$ method; per cent potassium, calcium, magnesium and sodium by dry ashing; per cent sulphur by dry ashing (Turbidimetric method); organic carbon by ashing method. The statistical analyses were done using m-stat computer program.

Table 3. Chemical composition of mustard meal (%).

State of meal	N	P	K	Ca	Mg	Na	S	OC	C:N
Fresh meal	6.1	0.93	0.97	0.06	0.13	0.82	0.62	88.5	14.51
Decayed meal	4.4	0.87	0.84	0.06	0.13	0.81	0.54	74.0	16.82

RESULTS

Field experiments at Ginchi (Pellic Vertisol)

Significant ($P < 0.01$) grain yield increase for the organic N levels was recorded on the Pellic Vertisol (Table 4). In 1991/92 the grain yield increase over the control varied from 217 to 1121% with the increase of the N rate from 60 kg to 180 kg ha^{-1}. During the same period the yield increase of wheat due to urea nitrogen on the same site varied from 516–550% with the increase of the nitrogen rate from 60–180 kg ha^{-1} (IAR, 1993). Similarly, during the 1992/93 and 1993/94 crop seasons the effect of mustard meal was highly significant and the yield increase varied from 0.56 to 1.95 and 0.89 to 2.44 t ha^{-1}, respectively (Table 4). The increase in the grain yield of wheat was linearly related to the mustard meal nitrogen rate for fresh and decayed meal in 1991/92 with r values of 0.98 and 0.96, respectively. The corresponding values for 1992/93 and 1993/94 were 0.98 and 0.97 and 0.99 and 0.95, respectively. During all the experimental period there was no significant effect due to the state of the meal.

Table 4. Effect of mustard meal application on the growth and yield of wheat [t ha^{-1}] grown on a Pellic Vertisol at Ginchi, Ethiopia (1991/92–1993/94).

N rate kg ha^{-1}	Year					
	1991/92		1992/93		1993/94	
	Fresh	Decayed	Fresh	Decayed	Fresh	Decayed
0	0.28	0.29	0.39	0.40	0.24	0.28
60	1.20 (329)	0.92 (217)	0.99 (153)	0.96 (139)	1.17 (338)	1.17 (314)
90	2.33 (732)	1.15 (297)	1.72 (343)	1.83 (354)	1.33 (445)	1.36 (384)
120	2.54 (807)	1.24 (328)	1.77 (450)	1.81 (354)	1.81 (655)	1.88 (564)
180	3.42 (1121)	2.54 (776)	2.34 (526)	2.52 (501)	2.68 (1017)	2.94 (939)
Mean	1.95 (747)	1.23 (404)	1.44 (368)	1.50 (337)	1.45 (629)	1.53 (550)
	Type	N rate	Type	N rate	Type	N rate
SE	0.40	0.68	0.35	0.16	0.30	0.12
LSD (0.05)	Ns	0.20	Ns	0.47	Ns	0.36
(0.01)	Ns	0.28	Ns	0.64	Ns	0.50
CV %	11.22		23.78		20.30	

Figures in parentheses are per cent yield increase over the control.

The calculated agronomic efficiency (AE) of mustard meal nitrogen application on Pellic Vertisol showed similar trend to the grain yield and varied from 7.92 to 22.78 kg grain per kg N applied as mustard seed meal (Table 5). The highest AE was obtained during the 1991/92 cropping season when mustard seed meal nitrogen was applied at the rate of 90 kg ha^{-1}. The lowest AE was also recorded during the same year when the rate of N was 120 kg ha^{-1}.

Field experiments at Holetta (Eutric Nitosol)

On the Nitosol the effect of mustard seed meal nitrogen on wheat grain yield was not statistically significant during the 1991/92 and 1992/93 crop season (Table 6). However, there was significant effect of mustard meal nitrogen on the grain yield of wheat ($P \leq 0.05$) in the 1993/94 crop season. The highest grain yield increase of 105% or 2.27 t ha^{-1} was obtained when 180 kg N ha^{-1} was applied as mustard meal.

Table 5. Agronomic efficiency (AE) of mustard meal nitrogen application on a Pellic Vertisol at Ginchi, Ethiopia (1991/92 – 1993/94).

N rate kg ha^{-1}	Year					
	1991/92		1992/93		1993/94	
	Fresh	Decayed	Fresh	Decayed	Fresh	Decayed
0						
60	15.33	10.50	10.00	9.33	15.50	14.83
90	22.78	9.56	14.78	15.89	10.44	12.00
120	18.83	7.92	11.50	11.75	11.83	13.33
180	17.44	12.50	10.83	11.78	13.56	14.78

Table 6. Effect of mustard meal application on the growth and yield of bread wheat [t ha^{-1}] grown on an Eutric Nitosol at Holetta, Ethiopia (1991/92 – 1993/94).

N rate kg ha^{-1}	Year					
	1991/92		1992/93		1993/94	
	Fresh	Decayed	Fresh	Decayed	Fresh	Decayed
0	1.70	2.00	3.65	3.61	2.25	2.16
60	1.40	2.20	3.22	3.36	2.86 (27)	3.47 (61)
90	1.80	1.90	3.70	3.56	3.37 (51)	3.51 (63)
120	1.90	2.40	3.97	3.38	3.62 (61)	3.77 (74)
180	1.90	2.10	3.28	3.36	3.90 (73)	4.43 (105)
Mean	1.74	2.12	3.56	3.45	3.20 (42)	3.47 (60)
	Type	N rate	Type	N rate	Type	N rate
SE	0.14	0.27	0.06	0.27	0.14	0.29
LSD (0.05)	Ns		Ns	Ns	Ns	0.87
(0.01)	Ns	Ns	Ns	Ns	Ns	1.20
CV %	28.17		28.97		21.25	

Figures in parentheses are per cent yield increase over the control.

The agronomic efficiency (AE) of mustard meal nitrogen application on Eutric Nitosol was either negative or very low during 1991/92 and 1992/93 crop season (Table 7). In 1993/94 the AE varied from 9.17 to 21.83. The highest and lowest AE were obtained when the nitrogen from mustard meal was applied at the rate of 60 and 180 kg N ha^{-1}, respectively.

Greenhouse experiments

The nitrogen derived from mustard seed meal (% Ndf mm) on the the Vertisol varied from 18.38 to 39.82% (Table 8). The highest per cent Ndf mm was obtained when the N was applied at the rate of 40 mg kg^{-1} soil. The per cent mustard meal nitrogen use efficiency (% mm NUE) varied from 17.73 to 62.00. The highest % mm NUE of 62.00 was obtained at the lowest rate of mustard meal nitrogen application (10 mg N kg^{-1} soil).

The N derived from mustard seed meal (% Ndf mm) on the Nitosol varied from 25.17 to 70.67% (Table 8). The highest % Ndf mm was obtained when the N from the mustard meal was applied at 60 mg kg^{-1} soil. The mustard meal nitrogen use efficiency (% mm NUE) was also high on the Nitosol and varied from 43.00 to 62.18%. The highest % mm NUE was recorded when the nitrogen was applied at the rate of 20 mg N kg^{-1} soil.

There was no significant yield difference due to the residual effect of mustard meal application on rape-seed at Holetta that followed wheat. On Vertisol at Ginchi the crop establishment was very poor. The yield was also very low and there were differences neither in crop stand nor in yield.

Table 7. Agronomic efficiency (AE) of mustard meal nitrogen application on an Eutric Nitosol at Holetta, Ethiopia (1991/92 - 1993/94).

N rate kg ha^{-1}	Year					
	1991/92		1992/93		1993/94	
	Fresh	Decayed	Fresh	Decayed	Fresh	Decayed
0						
60	-5.00	3.33	-7.17	-4.17	6.00	21.83
90	1.11	-1.11	0.56	-5.56	12.44	15.00
120	1.67	3.33	2.67	-1.92	11.42	13.42
180	1.11	0.56	-2.06	-1.39	9.17	12.61

Table 8. Nitrogen uptakes by bread wheat (ET-13) from mustard meal under greenhouse condition, Holetta, Ethiopia (1995).

N rate	Per cent N derived from mm		Per cent mustard meal N use efficiency	
	Vertisol	Nitosol	Vertisol	Nitosol
10 mg N kg^{-1} soil	18.38	25.17	62.00	61.63
20 mg N kg^{-1} soil	28.89	41.18	40.86	62.18
30 mg N kg^{-1} soil	36.37	54.73	38.10	59.15
40 mg N kg^{-1} soil	39.82	58.20	33.26	43.00
60 mg N kg^{-1} soil	29.75	70.67	17.73	43.32
CV	22.27	10.94	20.92	17.97
LSD (0.05)	10.54	1.86	12.37	3.29
(0.01)	14.78	2.28	17.35	4.03

DISCUSSION

Mustard seed meal nitrogen application significantly increased the grain yield of wheat on the Vertisol during all the experimental period. On Eutric Nitosol the yield from the control plot was relatively high and the yield increase was not statistically significant for two seasons (1991/92 and 1992/93). There was no moisture stress during the experimental period (Table 1). The rainfall amount, monthly distribution and the mean maximum and minimum temperature during the growing period (June to October) were favourable at both locations. The high efficiency of the mustard meal on the Pellic Vertisol might be due to the near to neutral pH of the Vertisol which is more favourable for most soil microorganisms decomposing organic residue (Rosswall and Paustian, 1984: Tinker, 1984). The soil nitrogen content is also lower in Pellic Vertisol than in the Eutric Nitosol (Table 2). On this soil in addition to the high yield increase due to mustard meal N;, problems such as plant lodging due to vigorous vegetative growth which usually occurs with high N application rate was not observed. On the other hand prolonged growth and late maturity was observed following perhaps improvement of the physical condition of the soil and the slow release (mineralization) of the mustard meal nitrogen that is present in the form of crude protein in the residue (Cooke, 1982; Gupto *et al.*, 1988; Huc, 1988, Sharama and Deb, 1988).

The observed statistically insignificant yield difference on Eutric Nitosol for the first two seasons might be due to lower pH and higher nitrogen content compared to the Pellic Vertisol. The yield of the control was also high during all the experimental period (Table 6).

The other positive value of mustard meal application was its suppression of soil borne cereal pathogens. This quality of mustard seed meal was not investigated under the present study. However, brassica green manure, rotation crops or seed meal amendments have been reported to suppress pest and disease organisms when grown or incorporated in the soil (Kirkegaard *et al.*, 1995; 1996; Sarwar and Kirkegaard, 1998). This value of the mustard meal might have contributed to the better performance of bread wheat on Vertisol than on Nitosol. As it is well known, waterlogging is one of the major yields limiting factors on Vertisols.

The calculated AE of mustard meal nitrogen application showed similar trend to that of the grain yield on both soil types. On the Pellic Vertisol AE of mustard meal nitrogen application was greater than 10 kg grain per kg nitrogen applied in most of the treatments (Tables 5 and 7). On the Eutric Nitosol it was only in the 1993/94 cropping season that the AE was greater than 10 kg grain per kg nitrogen applied as mustard seed meal.

The fertilizer nitrogen use efficiency was measured using isotopic method by estimating the amount of nitrogen derived from the applied labelled ^{15}N fertilizer by the crop (Hamersen and Morgaham, 1988; Rao *et al.*, 1992). The nitrogen uptake by bread wheat on Nitosol and Vertisol was highly significant. The per cent nitrogen derived from mustard meal (% Ndf mm) increased with the increase in the rate of nitrogen applied per kg soil on both soils. It is known that the per cent nitrogen use efficiency decreases with an increase in the rate of application (Power *et al.*, 1986; IAEA, 1990). However, the range recorded for this greenhouse experiment was very large.

CONCLUSION

The results of the field experiments and the calculated AE of mustard meal nitrogen showed the high value of mustard seed meal as an organic source of nitrogen. In addition, the findings of the greenhouse studies also showed that there was significant uptake and use efficiency of nitrogen on both soil types confirming the findings of the field experiment. Hence, we recommend further verification of the result on farmers fields to establish recommendation. The authors would also like to suggest the initiation of studies on biofumigation of mustard seed meal.

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