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INFLUENCE OF SEED RATE AND LEAF TOPPING ON SEED YIELD, OIL CONTENT AND ECONOMIC RETURNS OF ETHIOPIAN MUSTARD *(Brassica carinata)*

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Ethiopian mustard (*Brassica carinata*) seed rate and leaf topping experiment was conducted in Ethiopia at Adet experimental station and on farmers' fields, for two consecutive years (2005-2006). Complete factorial combination of four topping treatments (no topping, topping at 20, 30 and 40 days-after emergence) and four seed rates (4, 6, 8, and 10 kg/ha) were tested in a randomized complete block design with three replications at each year. Leaf topping caused reduction in thousand seeds weight, seed and oil yield as compared to non-topping. From the experiment it was concluded that if the objective of the Ethiopian mustard production is for higher oil production, it should be planted at 8 kg/ha seed rate and avoiding leaf topping practice. However, if the objective of the production is for grain as well as leaf yields, planting it at a seed rate of 10 kg/ha and topping it 40 days after emergence is the best-recommended practice.
Keywords: Ethiopian mustard, leaf topping, seed, oil content

INTRODUCTION

Ethiopian mustard (*Brassica carinata*) is a crop from Ethiopia related to rapeseed (*B. napus)* (Abel, 2007; Wikipedia, 2012). The crop has a significant place in the long-lived traditional agricultural practice of Ethiopia dating back in the 4th and 5th millennia (Abel, 2007; Wikipedia, 2012). *B. carinata* is found exclusively in Ethiopia but, recently it has been cultivated in Zambia, Sera Leon, Guinea, India, China, Bangladeshi, Indonesia Eastern Europe and U.S.A. (Abel, 2007). Ethiopian mustard is known for its agronomic qualities which are rare or absent in other oilseed *Brassica* species, these include relatively large seed size (Getinet 1997), high heat and drought tolerance and reduced amount of seed shattering (Adefris, 2004; Abel, 2007; IENICA, 2004; Abebe *et al*., 2010). It is also resistance to many insect pests and diseases (IENICA, 2004). Evaluation of the prospect for *B. carinata* as an oilseed crop for India indicated that it performed much better than *B. juncea, B. napus and B. campestris*, in terms of seed and oil yield (Setia *et al*., 1995). Recently, Ethiopian mustard gained the interest of researchers in Canada and Spain because of its agronomic qualities.

In Ethiopia, both the leaves and seeds of Ethiopian mustard are consumed (Abel, 2007). The leaves are cooked as a vegetable and the seeds are used for oil extraction. As an oilseed crop, its cultivation is restricted only to Ethiopia (Adefris and Heiko, 2011). Ethiopian mustard forms are characterized by the presence of a high concentration of erucic acid in their oil (Abel, 2007). This feature makes it harmful for human consumption if it is taken in large doses. Presence of high content of glucosinolates and erucic acid inhibit large-scale expansion of the crop as export oil (Wijnands *et al*., 2009). However, interest in this species for industrial uses has been increasing. The oil finds wide application in the production of water repellents, waxes, polyesters lubricants, bio-diesel, bio-fumigants, leather tanning, varnishes, paints, soap and lamps (FAO, 2003; Adefris, 2004; Abebe *et al*., 2010).

Regarding the crops growth and development, soils ranging from acid to alkaline with moderate moisture are suitable for optimum growth of the crop (Abel, 2007). Ethiopian mustard producing farmers are widely practicing leaf topping. The farmers reported that the leaf topping practice will boost the seed yield by increasing the number of branches per plant. They also stated the topped leaf have important role in alleviating food shortage particularly at the beginning of the rainy season. The Ethiopian national average yield of the crop is low, 0.95 t/ha (Abebe *et al*., 2010). There is a wide gap with what could be realized by employing improved management practices (Nigussie and Yeshanew, 1991). Farmers are using high and variable seed rates. Maintenance of optimum plant population is essential for getting good harvests of rape seed and mustard (Ahlawat, 2007). Therefore, this study was conducted to determine the effects of topping and seed rates on seed yield and oil content of Ethiopian mustard.

MATERIALS AND METHODS

The experiment was conducted for two consecutive cropping seasons in the years 2005 and 2006. Each year the experiment was conducted on two sites, one at Adet main station and one on near-by farmers' field. The altitude of the experimental area is 2240 m.a.s.l. It receives a mean total annual rainfall of 1156.9 mm of which about 70 % are received during the main cropping season in the months from June to September. It has average daily maximum and minimum temperatures of 26.1^0C and 9.7^0C, respectively. The experimental area has a nitosol soil with an average soil P^H of 5.17, available P (Olsen) 1.688, total N % 0.0949 and organic matter % of 5.17. Complete factorial combinations of four topping levels (no topping, topping at 20, 30 and 40 days after emergence) and four seed rates (4, 6, 8 and 10 kg/ha) were tested in a randomized complete block design with three replications. Data was collected on plant height, number of branches/plant, leaf yield, grain yield, 1000-seed weight and oil content. The collected data were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) Version 9.2 (SAS, 2002). Besides economic analysis was performed following the CIMMYT partial budget analysis methodology (CIMMYT, 1988). An Ethiopian mustard seed cost/price of Ethiopian Birr (ETB) 7/kg, Ethiopian mustard leaf price of ETB 2/kg and labour cost of ETB 20/man day were used for the economic analysis. 1USD is currently exchanged for 17.2 ETB. Following the CIMMYT partial budget methodology, first total variable costs (TVC), gross benefits (GB) and net benefits (NB) were calculated. There after treatments were arranged in the order on increasing TVC. In the next step dominance analysis were performed to exclude dominated treatments from the marginal rate of return (MRR) analysis. A treatment is said to be dominated if it has a higher TVC than the treatment which has lower TVC next to it but having a lower NB. A treatment which is non-dominated and having a MRR greater than one and having the highest NB is said to be economically profitable.

RESULTS AND DISCUSSION

The combined analysis of the two years results exhibited that Ethiopian mustard seed yield is significantly affected by leaf topping time, seed rate and their interaction (Table 1 and Table 2). Regarding leaf topping, the highest seed yield was obtained with non-leaf topped mustard out yielding topped ones by a minimum of 235 kg/ha. Though in a related crop species, rapeseed (*Brassica napus* L), a number of authors reported leaf topping reduce the seed yield (Labana *et al*, 1987; Rahmat *et al*., 1994; Rahmat[a] *et al*., 2007). Raut and Ali (1986) found a considerable seed yield decrease of Indian mustard when topping is undertaken 40 and 60 days after sowing. In conformity to the mentioned reports, Rahmat[b] *et al*., (2007) said that compared to un-topped plants, the seed yield of rapeseed was found significantly reduced when it is topped at pre bud and bud stages of growth. Reducing size of the leaf canopy during the

Table 1. Analysis of variance for leaf topping time, seed rate and their interaction on Ethiopian mustard yield components (combined data of 2005 and 2006 seasons)

Source of variation	Grain yield (kg/ha)	1000 kernel wt.(g)	Plant height (cm)	Number of branches/ plant	Leaf Yield (kg/ha)
Leaf Topping (T)	**	**	**	*	**
Seed rate (S)	**	NS	NS	**	**
T x S	**	*	NS	NS	NS
CV%	26.3	12.4	7.1	26.3	29.9

**, * significance at 1% and 5% level, respectively. NS non-significance

Table 2. Effect of seed and leaf topping time on the seed yield (kg/ha) of Ethiopian mustard (combined data of 2005 and 2006 seasons)

Seed rate (kg/ha)	Topping time (DAE)				
	No topping	**Topping 20 DAE**	**Topping 30 DAE**	**Topping 40 DAE**	**Mean**
4	1375	1170	1358	1323	1306
6	1222	1379	1197	1185	1246
8	1592	1252	1069	1067	1245
10	1538	985	1032	1007	1141
Mean	1432	1196	1164	1145	
C.V (%)			26.3		
LSD (5%)	Topping (T)	Seed rate (S)	TxS		
	131.4	131.4	262.8		

vegetative phase of growth limits the amount of assimilates available for developing stem and root which have an important role in determining the yield potential of oilseed rape. Concerning the seed rates across the different leaf topping practices, it was the lowest seed rate, 4kg/ha, that exhibited the highest mustard grain yield (Table 2). An augmentation in grain yield was recorded from the higher to lower seed rate; the lower seed rate (4 kg/ha) exhibited a higher grain yield (1306). In line to the present study many reports state that *Brassica spp*. generally requires lower seed rates. IENICA. (2004) stated that Ethiopian mustard is much more vigorous and branched than rapeseed; therefore it requires lower plant densities. In comparable to this Ahlawat, (2007) recommended a seed rate of 4-10 kg/ha for the Indian mustard (*B. nupus*) depending on type of crop variety. With reference to the interaction of the two factors, the highest mustard grain yield (1592 kg/ha) was obtained when the mustard was planted at 8kg/ha seed rate and no leaf topping was undertaken.

Plant height, was significantly affected only by the single effect of leaf topping (Table 1 and Table 3). Seed rate and its interaction with leaf topping were found to have non-significant effect on the plant height of Ethiopian mustard. Among topping treatments, the highest plant height (180.6 cm) was observed with no leaf topping. Similarly (Khan *et al*., 2003; Labana *et al*., 1987 and Rahmat[b] *et al*., 2007) reported that when the related crop, *Brassica napus*, is topped, it resulted in plant height reduction.

Statistically significant response on the number of branches per plant was observed to the single effects of leaf topping and seed rates but not to their interaction (Table 1 and Table 4). The number of branches was increased when leaf topping was practiced. This finding is in contrast to many other previous topping experiments on *Brassica napus* which reported a reduction in number of branches per plant when topping is undertaken (Labana *et al*., 1987; Rahmat[b] *et al*., 2007). However, similar to the present observation Muhammad *et al.*, (2010) reported increase in number of branches plant^{-1} of chickpea with leaf topping. The highest branch number (14.9) was realized when the leaf topping was practiced 40 days after emergence (Table 4). The branching was observed to decrease with increase in the seed rate and hence the highest number of branch (15.4) was associated with the lowest seed rate, 4kg/ha (Table 4).

Thousand seeds weight was found to be significantly affected by leaf topping and the interaction of leaf topping with seed rate (Table 1 and Table 4). Among the leaf topping treatments, the highest mustard thousand seeds weight (3.8 g) was obtained when no leaf topping is practiced. In line with this statement Rahmat *et al*., (2000)

Table 3. Effect of seed rate and leaf topping time on the plant height (cm) of Ethiopian mustard (combined data of 2005 and 2006 seasons)

Seed rate (kg/ha)	Topping time (DAE)				
	No topping	Topping 20 DAE	Topping 30 DAE	Topping 40 DAE	Mean
4	183.5	170.3	176.2	168.5	174.6
6	175.5	168.5	167.3	171.0	170.6
8	182.3	166.8	166.8	167.3	170.8
10	181.3	169.4	168.7	164.1	170.9
Mean	180.6	168.7	169.8	167.7	
C.V (%)			7.04		
LSD (5%)	Topping (T)		Seed rate (S)		TxS
	4.9		NS		NS

Table 4. Effect of seed rate and leaf topping time on the number of branches/plant and thousand seed weight of Ethiopian mustard (combined data of 2005 and 2006 seasons)

Seed rate (kg/ha)	No of branches/plant					1000 seed weight (g)				
	Topping time (DAE)					Topping time (DAE)				
	No topping	Topping 20 DAE	Topping 30 DAE	Topping 40 DAE	Mean	No topping	Topping 20 DAE	Topping 30 DAE	Topping 40 DAE	Mean
4	12.9	15.9	16.5	16.3	15.4	3.6	3.5	3.5	3.9	3.6
6	13.8	16.2	14.7	15.5	15.1	3.9	3.6	3.6	3.3	3.6
8	13.2	13.0	15.8	14.4	14.1	3.9	3.7	3.6	3.6	3.7
10	11.2	14.1	12.0	13.5	12.7	3.7	3.4	3.7	3.2	3.5
Mean	12.8	14.8	14.7	14.9		3.8	3.6	3.6	3.5	
C.V (%)			26.34					12.42		
LSD (5%)	T		S		TxS	T		S		TxS
	1.525		1.525		NS	0.1807		NS		0.3615

and Labana *et al*., (1987) stated thousand seeds weight was found higher in un-topped rapeseed compared to topped ones. With reference to the interaction of the two factors, the lowest thousand seeds weight (3.2 g) was obtained when the mustard was planted at 10kg/ha seed rate and the leaf is de-topped 40 days after the crop's emergence.

Mustard leaf yield was significantly affected by the single effect of topping and seed rate but not by the interaction of the two factors (Table 1 and Table 5). Among the toppings, leaf topping 40 days after the crop's emergence gave the highest (4566 kg/ha) leaf yield. With respect to the seed rates it was at the highest seed rate (10 kg/ha) that the highest leaf yield (3972 kg/ha) was realized (Table 5).

Seed oil content laboratory analysis indicates that the non-topped Ethiopian mustard generally have higher seed oil content than the topped ones (Table 6). This remark is supported by Labana *et al*., (1987) who found that defoliation led to reduced oil yield of rapeseed. Generally the highest seed oil content of mustard seeds was observed when no leaf topping is practiced and at the lower seed rates (4-6 kg/ha). Hence, here it could be emphasized here that the Ethiopian mustard leaf is de-topped and used as vegetable just at the expense of the seed and oil yield.

The economic analysis, with the consideration of the seed and leaf yield, indicated that planting Ethiopian mustard at a seed rate of 6 kg/ha and topping it 40 days after emergence was the most profitable practice (Table 7). The seed yield reduction was much compensated by the topped leaf yield value. This is in harmony with the finding of Raut and Ali (1986) who concluded the returns from yield of fresh fodder completely compensated for the loss of seed yield in the defoliation and made rape seed topping profitable. According to Rahmat[a] *et al*., (2007) the net return from rapeseed production was higher when it is topped and the

Table 5. Effect of seed rate and leaf topping time on the leaf yield (kg/ha) of Ethiopian mustard (combined data of 2005 and 2006 seasons)

Seed rate (kg/ha)	Topping time (DAE)			
	Topping 20 DAE	Topping 30 DAE	Topping 40 DAE	Mean
4	1847	3444	3833	3042
6	1806	4014	4597	3472
8	2028	4125	4778	3644
10	2097	4764	5056	3972
Mean	1944	4087	4566	
C.V (%)		29.9		
LSD (5%)	Topping (T)	Seed rate (S)	TxS	
	104.2	104.2	NS	

Table 6. Response of Ethiopian mustard seed crude oil content (%) to leaf topping time and seed rates (combined data of 2005 and 2006 seasons)

Seed rate (kg/ha)	Topping time (DAE)				
	No topping	Topping 20 DAE	Topping 30 DAE	Topping 40 DAE	Mean
4	37.8	36.4	36.1	35.3	36.4
6	37.6	35.1	35.0	35.2	36.0
8	36.9	36.1	34.6	35.7	35.6
10	35.8	34.6	35.5	35.4	35.3
Mean	36.8	35.55	35.3	35.4	
C.V (%)			29.9		
LSD (5%)	Topping (T)	Seed rate (S)	TxS		
	1.24	1.24	NS		

Table 7. Economic analysis result of Ethiopian mustard leaf topping time and seed rate (Combined data of 2005 and 2006 seasons)

TRT	Grain yield (kg/ha)	Leaf yield (kg/ha)	Total variable cost (Birr/ha)	Net Benefit (Birr/ha)	MRR (%)
1S1	1375	0	28	9600	
T1S3	1592	0	56	11087	5310
T4S1	1323	3833	108	16817	11019
T4S2	1185	4597	122	17365	3917

T1= no topping, T4= topping 40 DAE, S1= 4kg/ha, S2= 6kg/ha, S3= 8kg/ha

leaf sold as vegetable as well as the plant produce rape seed yield with a 20% economic advantage compared to the un-topped rapeseed (Rahmat[a] *et al*., 2007). It therefore is the best to recommend the specified treatment if the objective of the mustard production is for leaf and seed yield. However, for the objective of producing a higher mustard seed with the best thousand seeds weight and higher seed oil content, it was found best to plant the Ethiopian mustard at 8 kg/ha seed rate and avoiding leaf topping practice.

Conclusion: From this Ethiopian mustard seed rate and leaf topping experiment it is concluded that if the objective of the mustard production is for higher seed yield as well as oil production, it should be planted at 8 kg/ha seed rate and avoiding the leaf topping practice. However, if the objective of the production is for seed yield as well as leaf yields, planting Ethiopian mustard at a seed rate of 10 kg/ha and topping it 40 days after emergence is the best-recommended practice.

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