Research Article

Profitability and Physiological Traits of Canola as Affected by Various Green Manure Management Scenarios and Inorganic Nitrogen Application

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Abstract | Integration of green manuring crops along with the inorganic fertilizers in the prevailing cropping system may increase crop productivity and net profitability through improving soil physico-chemical properties and fertility. Two years field experiments were conducted at the Agriculture Research Institute Tarnab, Peshawar- Pakistan (semiarid conditions) to investigate the effect of two green manuring crop species (guar and millet), their incorporation age (40, 70 and 100 days after sowing, DAS) and parts (whole plants incorporation and stubbles incorporation) under varying nitrogen levels (0, 75 and 100 kg ha^{-1}) on physiology, yield and economic returns of Canola (*Brassica napus* L. cv. Bulbul-98). The experiments were laid out in randomized complete block design with split plot arrangement having three replications. Findings of the experiment revealed that guar as previously green manuring crop considerably increased leaf area index (LAI) 4.4, crop growth rate (CGR) 5.7 g m^{-2} d^{-1}, seed yield (2329 kg ha^{-1}) and harvest index (22.10%). Incorporation of whole plant had significantly increased LAI (4.1), seed yield (2226 kg ha^{-1}) and harvest index (22.1%) of canola crop over stubbles incorporation. Decrease in CGR and grain yield was observed with delaying green manuring (40 > 70 > 100 DAS). Increase in LAI, CGR, grain yield and harvest index was noticed with increasing N rate (0 < 75 < 100 kg ha^{-1}). Increase in canola yield was observed during 2nd year of the experiment. A linear increase in seed yield of canola was observed with increase in N levels in both guar and millet sown as preceding green manuring crops irrespective of their age at incorporation. Calculating the economic returns guar incorporation after 40 days of sowing along with 100 kg nitrogen ha^{-1} resulted in higher value cost ratio (VCR) of 4.4 Hence, it was concluded that the inclusion of legumes and their incorporation either at 40 or 70 DAS coupled with 100 kg N ha^{-1} showed promising results and thus could be used for enhancing overall farm productivity and net economic returns of the farming community.

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Introduction

Cultivation of *Brassica* species (*Brassica napus* L. and *Brassica campestris* L.) on the marginal land with scarce rainfall is an old practice in the Indian sub continent. Due to low input requirements of these species and their major use as livestock fodder and feed (oil cake) the crop is grown on the borders/mar-

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gins of the field. The crude seed extracted oil is used in cooking by the low income families without considering its nutritional status. Recently, experiments were conducted across the country on its adaptability to various ecological zones. It was observed that although canola has low amounts of toxic compounds but its demand for plant nutrients (NPK and other) and water is comparatively higher than the conventional species. Majority of the farmers in Pakistan are small farmers and are reluctant to replace the conventional cultivars with canola having high cost of production, although the crop has the ability to adapt to the prevailing environmental conditions of Pakistan. The average yield is very low compared to advanced countries of the world (Reddy, 2004). The lesser yield in our country might be due to multiple reasons such as low soil fertility and lack of improved technology.

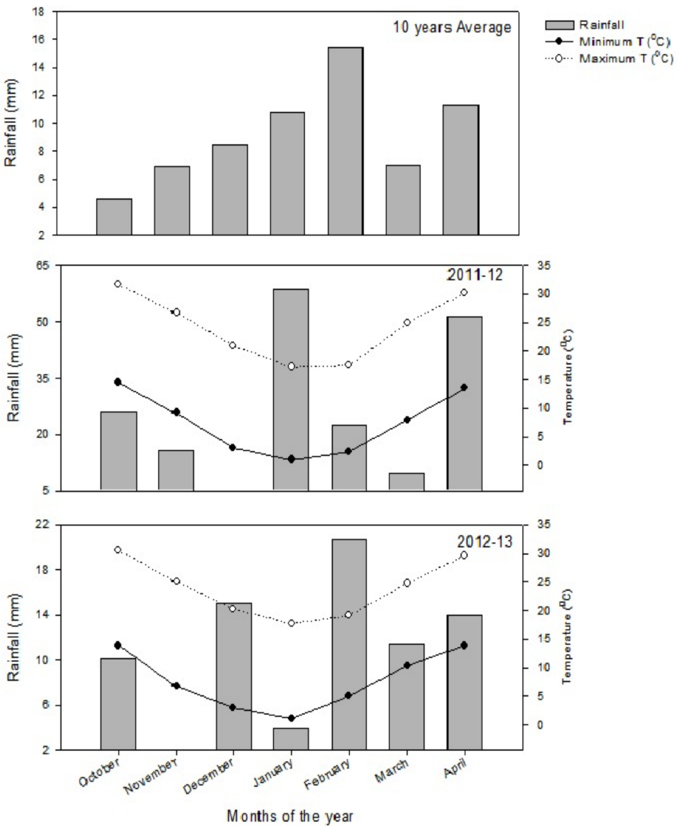

Figure 1: *Ten (10) years mean monthly rainfall (mm), Minimum and maximum temperature (°C) during the growing seasons 2011-12 and 2012-13, respectively*

Currently, Pakistan is heavily relying on the import of edible oil and spending about 2.50 billion US$ (GOP, 2013) to meet its local requirements. In order to bridge up the gap between the demand and supply and to minimize its dependence on the import of edible oil, efforts are under way with multidimensional approaches. Acclimatization of the crop for the soil or management of soil for crop is underway to boost canola production. For increasing land productivity and economic sustainability, management of low N soil is extremely important. Appropriate nutrient management can increase canola yield by application of balanced fertilizers (mineral and organic sources). The present study was aimed to improve the canola yield and fertility status of the soil through the application of both inorganic and organic sources of plant nutrients.

Nitrogen deficiency is one of the major factors adversely affecting the yield of the crops (Shah et al., 2003). The application of nitrogen fertilizers is a key factor in improving soil and plant attributes (Malhi et al., 2004). *Brassica* need higher dose of nitrogen and thus should be provided at proper time for higher yield (Cutforth et al., 2009; Malhi and Gill, 2006). According to Gan et al. (2008) and Malhi et al. (2007) 135 kg N ha^{-1} is required to obtain greater yield of *Brassica napus*. Likewise, Malidareh et al. (2010) and Cheema et al. (2001) also found considerable influence of N on yield and associated traits of canola.

Nutrients management through green manuring will improve soil fertility status on sustainable basis. The use of organic sources of fertilizers i.e. green manuring has increased substantially due to awareness and reduced input costs, often used by farmers because it is supposed to be more environmentally beneficial and less expensive than mineral fertilizers (Edmeades, 2003). Growing green manure crops in rotation is a vital part of organic farming systems. Green manures are plants accumulate nutrients for the main crop (Eyhorn et al., 2004). However, a number of factors including soil moisture, aeration, temperature, and the nature of the organic matter will affect the amount and timing of mineralization (Berry et al., 2002). Nitrogen that is fixed or taken up by the green manuring plants is released through the decomposition and become available to the subsequent crops. Addition of green manure will enhance nutrients pool of the soil, improve soil physical properties such as better aggregation, water holding capacity, infiltration and aeration (Wolf and Snyder, 2003). According to Thorup-Kristensen et al. (2003) soil chemical properties like cation exchange capacity and pH buffering is also improved with the application of organic sources nutrients. Green manure crops incorporation does not always improve yields instantly but over a time significantly as residues decomposition is a slow process and gradually improve soil organic matter (Stark et al., 2006). According to Eyhorn et al. (2004) the benefits of green manures occur over the long term and are not always visible immediately (Eyhorn et al., 2004). They not only serve as a ready source of nutrients but also have a great potential for increasing the availability of soil nitrogen to subsequent crop plants, for conserving nitrogen and enhancing fertility on sustainable basis (Ashraf et al., 2004). Thus integration of legume as green manuring crops with inorganic nitrogen may enhance nitrogen pool of soil and hence can be used as strategy for not only improving overall farm productivity in the existing cropping system but also help in environmental sustainability.

Materials and Methods

Experiment site and procedure

Field experiments were performed at ARI Tarnab, Peshawar, Pakistan which lies about 16 km toward east from Peshawar, the capital of Khyber Pakhtunkhwa province. Two short duration crops (millet and guar) were cultivated during kharif 2011 and were given cut at 40, 70 and 100 days after sowing. A known amount of biomass was taken from each treatment based on their tissue N contents. The biomass was chopped into smaller pieces and was then incorporated in the soil or removed as per treatments. However for removal treatment, the underground portion i.e. stubbles and roots were incorporated. Canola (cv. Bulbul-98) was planted at seed rate of 5 kg ha^{-1} during Rabi 2011 on those summer incorporated plots. A subplot size of 20 m^2 having 8 rows 5 m long with 50 cm row to row distance was used for two consecutive years. Phosphorus and potash as basal dose was applied each at rate of 60 kg ha^{-1} at seed bed preparation to each subplot. The experiment was laid out in randomized complete block design having split plot arrangement with three replications. Main plot consisted of crop age for green manuring (AGM) and crop species (C) whereas incorporation of crop as green manure (GM) and N levels (N) were allotted to sub plots.

Data recording procedure

Leaf area index was recorded through crop canopy analyzer (LI-2000, LI-COR, USA). The machine was adjusted for one above and three below reading to yield a single mean for LAI. Crop growth rate (g m^{-2} day^{-1}) was obtained by cutting 50 cm row on three different places in each sub plot at 30 days interval and was allowed to dry in oven at 80°C for 24 hours.

The following formula was used for CGR calculation (Radford, 1967):

$$\text{CGR} = \frac{Wt_2 - Wt_1}{T_2 - T_1} \times \frac{1}{Ground\ area}$$

Wt_1 = Initial weight
Wt_2= Final weight
T_1 and T_2 = Time intervals

Seed yield was recorded in kg ha^{-1} by threshing the dry biomass obtained from harvesting four rows in each subplot. Economic analysis were performed according to cost and income based on local market rates (Bholje and Eidman, 1984).

Statistical Analysis

The data obtained were subject to statistical analysis combined over years according to procedure suitable for randomized complete block design with split plot arrangement (Steel and Torrie, 1980) and upon significant differences among nitrogen levels and age at green manuring, mean comparison test was performed at 5% level of probability using LSD test.

Results and Discussion

Leaf area index

Leaf area index (LAI) of canola (Table 1) planted after guar had significantly higher LAI (4.4) than the one planted after millet (3.70). The plots where only stubbles were incorporated resulted in lower LAI (4.0) than the plot where whole plants were incorporated (4.1). Green manuring after 70 days of incorporation had maximum LAI (4.4) than from 40 days of incorporation (3.7). As nitrogen is an integral component of chlorophyll, thus have a direct positive effect on cell division and enlargement that consequently enhanced growth and yield of canola (Rakhte et al., 2005). Higher leaf area index of canola in guar incorporation as preceding green manuring at 70 DAS might be due to the optimum nutrients availability that promoted vigorous plant growth as leaf area and leaf area index is the results of higher photosynthates assimilation in plant tissues (Lopez-Bellido et al., 2005). Deldon (2001) observed the additive influence of leaf area index with the application of nitrogen from organic as well as inorganic sources due to the higher accessibility to nutrients, improving water holding capacity and decrease in volatilization of N fertilizers. Maximum LAI (4.4) was recorded for 100 kg N ha^{-1} whereas lower LAI (3.8) was recorded for control plots. The improvement in

Table 1: *LAI, CGR (gm^{-2}d^{-1}), seed yield (kg ha^{-1}), harvest index (%) of canola as affected by incorporation of green manuring crops at different stages under varying nitrogen levels*

	Leaf area Index	CGR (g m^{-2} d^{-1})	Seed Yield (kg ha^{-1})	Harvest Index (%)
Green mannuring Crops (C)				
Millet	3.7 b	5.4 b	1977 b	21.1 b
Guar	4.4 a	5.7 a	2329 a	22.1 a
Significance level	**	**	**	**
Green Mannuring (GM)				
whole plants	4.1 a	5.5	2226 a	22.1 a
stubbles only	4.0 b	5.6	2086 b	21.2 b
Significance level	**	Ns	**	**
Age at green mannuring AGM (Days)				
40	3.7 c	5.7 a	2326 a	22.3 a
70	4.4 a	5.7 a	2204 b	21.3 b
100	4.0 b	5.2 b	1938 c	21.3 b
$LSD_{(0.05)}$	0.2	0.2	159	0.9
Nitrogen levels (N) kg ha^{-1}				
0	3.8 c	5.0 c	1685 c	20.6 b
75	4.0 b	5.6 b	2300 b	22.1 a
100	4.4 a	6.0 a	2483 a	22.2 a
$LSD_{(0.05)}$	0.1	0.1	72	0.7
Year Means				
2011-12	3.8	5.4	1810 b	22.3 a
2012-13	4.3	5.6	2502 a	21.0 b
Interactions				
AGM x C	Ns	** (Figure 4)	ns	Ns
GM x N	Ns	* (Figure 5)	ns	** (Figure 12)
AGM x GM	Ns	ns	ns	Ns
AGM x N	Ns	**(Figure 6)	ns	Ns
AGM x GM x N	Ns	ns	ns	Ns
C x GM	Ns	ns	** (Figure 10)	Ns
C x N	Ns	** (Figure 7)	ns	Ns
C x GM x N	** (Figure 2)	* (Figure 8)	ns	Ns
AGM x C x GM	Ns	ns	ns	Ns
AGM x C x N	* (Figure 3)	* (Figure 9)	** (Figure 11)	Ns
AGM x C x GM x N	Ns	ns	ns	Ns

Means followed by dissimilar letters in each class are significantly different from each other at 5% and 1% level of probability; **ns** *stand for non significant*

leaf area index for maximum N level was mainly due to the sufficient N content in the tissues. Kibe et al. (2006) also reported greater leaf area index for 100 kg N ha^{-1} application. The results of this study are further supported by Bybordi and Ebrahimian (2013) and Hosseini et al. (2006) who reported significant increase in leaf area index in canola for higher nitrogen dose.

Interaction of C x GM x N revealed that leaf area index enhanced under higher level of N (Figure 2). However guar as green manuring crop was superior to millet, signifying that inclusion of legumes in the cropping system can attribute to the total N in soil, reduce N fertilizers input (Soon and Arshad, 2004; Zentner et al., 2001) and add ample organic matter to the soil through its incorporation and thus enhancing biotic activities, enhance physico-chemical characters of soil and improve availability of nutrients and thus added positive influence on the following crops (Choudhry, 1994). The three-way interaction between age at green manuring, crops species and mineral nitrogen as shown in Figure 3 revealed that LAI increased with the increasing N level irrespective of the crop species sown. Guar responded well to increasing N level and green manuring at 70 DAS than millet suggesting that increasing N level was probably the key element responsible for increasing the aforementioned trait. Increasing N level caused improved soil mineral N status (Meng et al., 2005), thus improved the chlorophyll in the canopy through N absorption generating larger photosynthetic surface area (Houles et al., 2007) and thus might had increased the leaf area index. Present findings are in line with Ngezimana and Agenbag (2013), Malmir et al. (2013) and Rashid et al. (2010) who also found improved leaf area index under higher N (120 kg ha^{-1} and 225 kg ha^{-1}).

of N (6 g m^{-2} d^{-1}). The higher CGR of canola under higher N level indicates the greater nitrogen requirement for promoting vegetative growth and hence the results are in line with Weiss (1983) who also narrated that N is closely associated with vegetative growth. Further, vegetative growth depends on the photosynthetic capabilities of the plant and increasing nitrogen fertilizers application improves the photosynthetic capabilities and growth of plants (Habtegebrial et al., 2007). The current findings are in accordance with Rashid et al. (2010) who recorded considerable deviation in CGR of different cultivars of mustard and concluded maximum CGR at maximum level of N. Likewise, the findings of Cheema et al. (2010) are also in line with our results who found maximum CGR of canola at 120 kg N ha^{-1}.

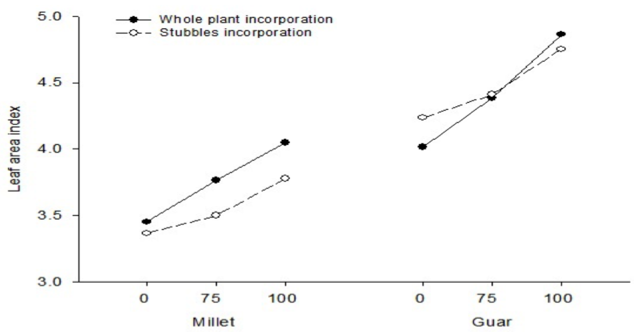

Figure 2: *Interaction between C x GM x N for leaf area index of canola*

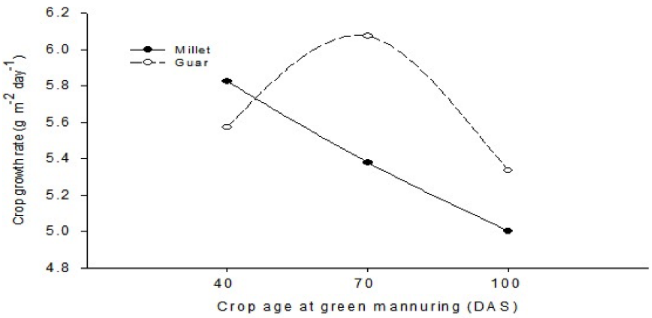

Figure 4: *Interaction between AGM x C for crop growth rate (g m^{-2} d^{-1}) of canola*

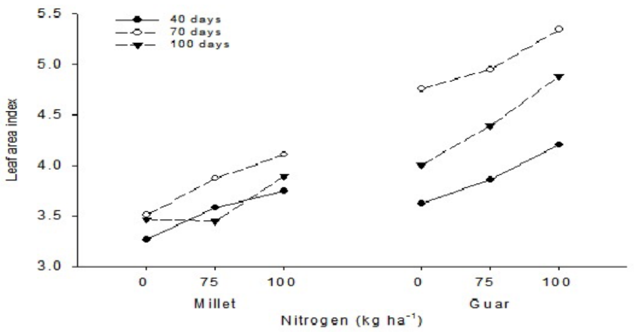

Figure 3: *Interaction between AGM x C x N for leaf area index of canola*

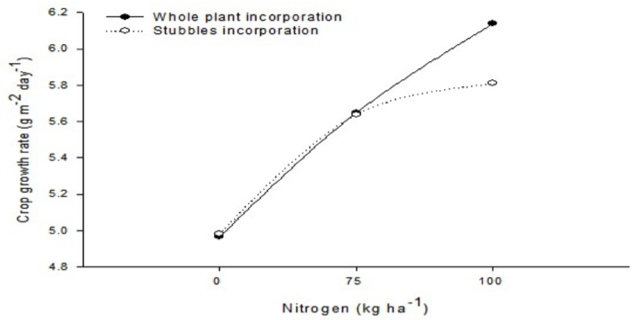

Figure 5: *Interaction between GM x N for crop growth rate (g m^{-2} d^{-1}) of canola*

Crop growth rate

Nitrogen which promote vegetative growth and grain formation (Balint et al., 2008) is required relatively in high amounts for oil seed crops as these crops are very responsive to fertilizers and required considerable amount of nitrogen (Cutforth et al., 2009; Malhi and Gill, 2004). Sowing of guar as previous green manure crop resulted in increase in CGR (5.70 g m^{-2} d^{-1}) than on millet incorporated plots. Crop growth rate significantly enhanced with green manuring either at 40 days or at 70 days (5.7 g m^{-2} d^{-1}) and increasing level

The significant interaction AGM x C as given in Figure 4 indicated that guar incorporated at 70 DAS resulted in higher CGR. The higher response of guar sown plots when green mannured at 70 DAS over millet showed that millet incorporation not later than 40 DAS is the best option for green manuring while delay incorporation of guar till 70 DAS can be a best alternative for maximum CGR. The interaction between GM x N (Figure 5) shows that N application was mainly responsible for increasing canola CGR and the role of green manuring seems negligible up to 75 kg N ha^{-1}. Whole plants incorporated plots and applied with 100 kg N ha^{-1} recorded maximum canola CGR as compared to plots added with stubbles only. The interaction between AGM x N (Figure 6) revealed increase in canola CGR with the increase in N level when green mannured at 40 or 70 DAS and applied with 100 kg N ha^{-1} while CGR at 100 DAS incorporated plots having 100 kg N ha^{-1} leveled off. The interaction between C x N (Figure 7) showed a linear increase in canola CGR with the increase in N level irrespective of the crop species. Guar sown plots produced more canola CGR without N application as compared with millet. The C x GM x N interaction (Figure 8) showed that with the increase in N level and green manuring of whole plants canola CGR increased except in guar where CGR leveled off at 100 kg ha^{-1} when whole plants were incorporated. Guar related plots have higher canola CGR at no N application. Canola crop growth rate of millet sown plots increased linearly with an increase in N level. The interaction of AGM x C x N (Figure 9) indicated that with the increase in N level canola CGR increased in both the crops irrespective of their age at incorporation. Response of millet sown plots to N was linear than guar. However, canola CGR in 70 DAS guar sown plots at no application was almost similar to those of millet at 40 DAS along with 75 kg N ha^{-1}. The present findings revealed that CGR enhances with higher N level irrespective of the crop species or green manuring age and thus could be the consequences of higher dry matter production in fertilized plots. Conservation and supplementation of organic residue provides vital natural resources for conserving soil productivity (Ortega et al., 2002), and thus might have improved crop growth rate. These findings are similar to Kibe et al. (2006) and Malmir et al. (2013) who reported higher CGR for increasing nitrogen up to 225 kg ha^{-1}.

Seed yield

Seed yield was considerably affected by green manuring of both cereal and legume crops, Nitrogen and age at incorporation. None of the interaction was found significant except C x GM and C x AGM x N. Maximum canola seed yield (2329 kg ha^{-1}) was obtained in plots planted after guar against 1977 kg ha^{-1} when canola was sown on preceding millet sown plots. Maximum seed yield (2226 kg ha^{-1}) of canola was produced by whole plants incorporated plots than stubbles only (2086 kg ha^{-1}). Plants incorporated at 40 DAS had maximum seed yield of 2326 kg ha^{-1} against minimum of 1938 kg ha^{-1} seed yield of canola at 100 DAS incorporation. The improved yield efficiency of canola in previously guar incorporated plots preferably at 40 ADS might be due to the residues influencing properties of the soil by enhancing fertility through nutrients cycling (Abdullah 2014, Lopez-Garrido et al., 2014, Halvorson et al., 2001b; Camara et al., 2003; Malhi et al., 2006), higher soil water content and more organic matter (Sing et al., 2004). Likewise, residue application might had improved soil characteristics including moisture retention, aeration and porosity and water infiltration that resulted in higher seed yield of canola. The present findings are in agreement with Christen (2001), Rathke et al. (2006) and Adjei-Nsiah et al. (2008) who also reported substantially lower seed yield when canola was sown after cereal crops as compared to when sown after legumes.

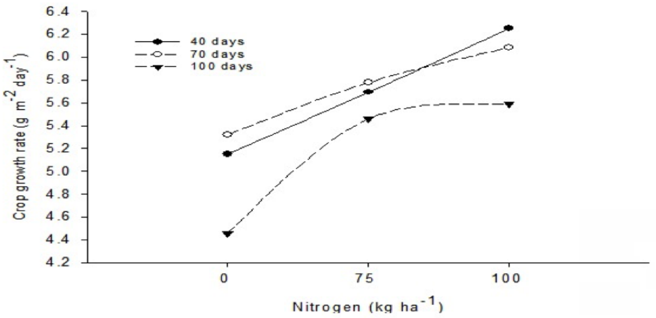

Figure 6: *Interaction between AGM x N for crop growth rate (g m^{-2} d^{-1}) of canola*

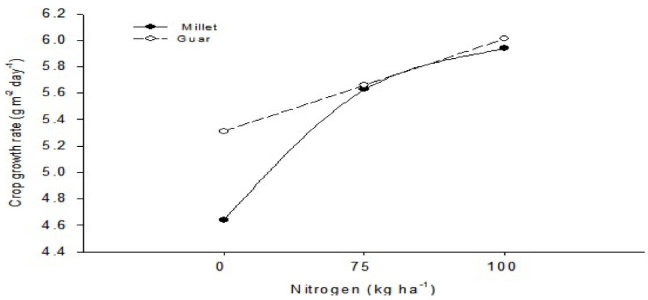

Figure 7: *Interaction between C x N for crop growth rate (g m^{-2} d^{-1}) of canola*

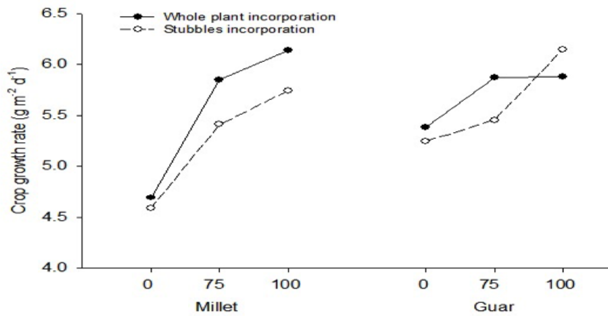

Figure 8: *Interaction between C x GM x N for crop growth rate (g m^{-2} d^{-1}) of canola*

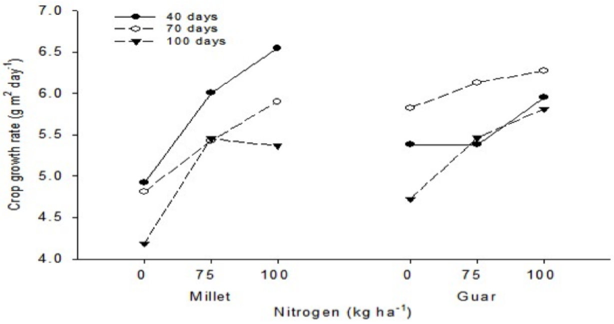

Figure 9: *Interaction between AGM x C x N for crop growth rate (g m^{-2} d^{-1}) of canola*

Increasing nitrogen up to 100 kg N ha^{-1} had enhanced seed yield of canola (2483 kg ha^{-1}) whereas minimum seed yield of 1685 kg ha^{-1} was produced in plots applied with no N. Our results are supported by Kazemeini et al. (2010), Ahmadi and Bahrani (2009), Naderifar et al. (2013), Buttar et al. (2006), Cheema et al. (2001), Oztruk (2010) who also found higher seed yield of canola for increase nitrogen application. The C x GM interaction revealed that whole plants incorporation of guar had greater seed yield as compared to millet incorporation (Figure 10). The interaction for AGM x C x N exhibited that incorporation of both species at 40 DAS had higher canola yield along with 100 kg N ha^{-1} though guar responded well to higher N as compared to millet at 40 DAS (Figure 11). The findings are parallel to Hejazi et al. (2010) and Aynehband et al. (2010). They concluded that incorporation along with mineral N provide an ideal condition for growth which had exhibited a pleasant impact on canola production. The probable reason for higher yield during 2nd year might be due to the fact that residual N from incorporation of green manure crops does not improve yield immediately, but over time increase significantly due to the gradual release of N, improvement in soil organic matter and soil physical and chemical properties (Stark et al., 2006).

Harvest index

Significant differences were recorded for harvest index due to Crops, GM, AGM and N levels and the interaction between GM x N (Table 1). Canola planted after guar resulted in higher harvest index (22.1 %) against 21.1 % when canola was sown after millet. Incorporation of whole plants resulted in maximum harvest index (22.1 %) than stubbles only incorporation (21.2 %). Higher harvest index (22.3 %) was recorded after 40 days of incorporation followed by 100 days of incorporation (21.3 %) which was similar to 70 days. harvest index was higher (22.2 %) when N was applied at 100 kg ha^{-1} while control plots had lower harvest index (20.6 %). The green manuring and nitrogen interaction revealed that incorporation of whole plants with no nitrogen application had higher harvest index whereas for stubbles incorporation, harvest index enhanced with addition of N (Figure 12). Significant effect of these factors was observed for seed and biological yield which revealed a proportional higher increase in seed yield which might had resulted in higher harvest index. Increasing N level seems to be the main factor for increasing the harvest index. The present results are similar to Cheema et al. (2001) and Saleem et al. (2001) who also concluded maximum harvest index for higher nitrogen levels.

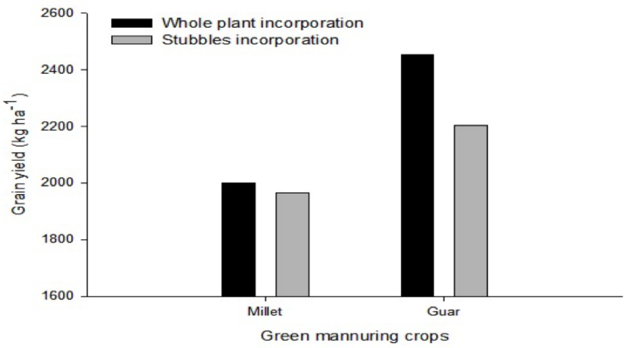

Figure 10: *Interaction between C x GM for seed yield (kg ha^{-1}) of canola*

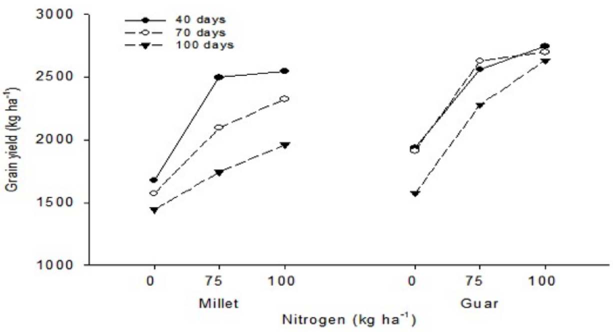

Figure 11: *Interaction between AGM x C x N for seed yield (kg ha^{-1}) of canola*

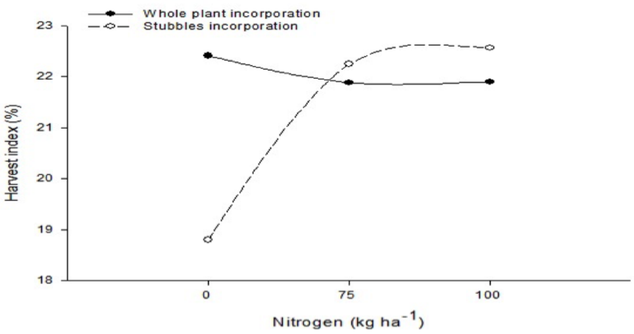

Figure 12: *Interaction between GM x N for harvest Index (%) of canola*

Economic analysis

Based on absolute values (Table 2), the higher value

Table 2: *Value cost ratio of canola crop in US dollars as affected by green manuring, green manuring crops, age at green manuring and mineral nitrogen*

Preceding crops	GM	Age (DAS)	N	Cost	Income (US$)					VCR
					Grain	Straw	Fodder	Gross	Net	
Millet	WP	40	0	414	1267	234	0	1501	1087	2.6
Millet	WP	40	75	474	2013	370	0	2383	1909	4.0
Millet	WP	40	100	493	2045	352	0	2397	1904	3.9
Millet	WP	70	0	434	1214	225	0	1439	1005	2.3
Millet	WP	70	75	493	1701	320	0	2021	1528	3.1
Millet	WP	70	100	513	1917	365	0	2282	1769	3.4
Millet	WP	100	0	454	1063	176	0	1240	786	1.7
Millet	WP	100	75	508	1481	288	0	1769	1256	2.4
Millet	WP	100	100	507	1555	311	0	1866	1333	2.5
Millet	SO	40	0	594	1387	285	495	2167	1772	3.0
Millet	SO	40	75	654	1943	339	634	2916	2462	3.8
Millet	SO	40	100	674	1983	322	594	2899	2425	3.6
Millet	SO	70	0	620	1274	296	594	2164	1769	2.9
Millet	SO	70	75	680	1618	281	614	2512	2059	3.0
Millet	SO	70	100	690	1763	325	723	2810	2337	3.4
Millet	SO	100	0	625	1221	265	1446	2932	2537	4.1
Millet	SO	100	75	690	1281	268	1485	3034	2580	3.7
Millet	SO	100	100	780	1550	290	1584	3425	2951	3.8
Guar	WP	40	0	414	1747	298	0	2046	1632	3.9
Guar	WP	40	75	490	2111	352	0	2463	1990	4.1
Guar	WP	40	100	493	2253	389	0	2642	2149	4.4
Guar	WP	70	0	434	1693	296	0	1989	1555	3.6
Guar	WP	70	75	493	2166	383	0	2548	2035	4.1
Guar	WP	70	100	499	2208	384	0	2592	2099	4.3
Guar	WP	100	0	454	1282	218	0	1500	1046	2.3
Guar	WP	100	75	513	1863	333	0	2196	1683	3.3
Guar	WP	100	100	533	2158	375	0	2533	2000	3.8
Guar	SO	40	0	594	1319	276	218	1813	1419	2.4
Guar	SO	40	75	654	1944	307	277	2528	2074	3.2
Guar	SO	40	100	674	2093	351	356	2801	2327	3.5
Guar	SO	70	0	620	1334	305	297	1936	1541	2.5
Guar	SO	70	75	680	1953	340	317	2610	2156	3.2
Guar	SO	70	100	690	2107	362	386	2855	2382	3.5
Guar	SO	100	0	625	1211	263	455	1930	1536	2.5
Guar	SO	100	75	690	1747	298	990	3036	2582	3.7
Guar	SO	100	100	780	2009	340	1028	3577	3103	4.0

GM = *Green Manuring;* **WP**= *Whole plants;* **SO** =*Stubbles only;* **N** = *Nitrogen*

cost ratio (4.4) was recorded in guar whole plants in corporation after 40 days coupled with 100 kg N ha^{-1} followed by the same treatment combination when incorporated at 70 DAS (4.3). Due to the inclusion of price of whole plant biomass removal (considering its fodder value in market point of view), its VCR resultantly dropped in comparison where no market value of stubbles was taken in to account. However it must be kept in mind that the impact of its incorporation will pay back on long term basis in the form of improving soil fertility. Along with higher economic profitability recorded for guar incorporation as whole plants either at 40 or 70 DAS combined with 100 kg N ha^{-1}, it is assumed that whole plants incorporation as green manuring had improved monitory returns on one hand while on the other hand also enhanced the canola yield and soil fertility. The results are in line with Gadgil et al. (2002) who also reported greater economic return with the incorporation of organic nutrients integrated with mineral nutrients.

Conclusion

It was concluded that preceding green manuring guar can be successfully adjusted in summer gap. Legumes had a pleasing effect on the subsequent canola crop both in terms of yield and economic profitability. Green manuring of whole plants incorporated preferably 40 to 70 DAS improved LAI, CGR, and seed yield. Likewise, N applied at 100 kg ha^{-1} significantly enhanced all the studied parameters. Guar as a green manuring crop incorporated as a whole plant after 40 days of sowing along with 100 kg N ha^{-1} resulted in greater value cost ratio (4.4).

Author's Contribution

I, Khalid Ali, is the major author of the manuscript. The contents of the manuscript are based on my PhD research work. Dr. Amanullah Jan was my supervisor who assisted me in writing and compiling my thesis and this article as well.

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