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SEED BLENDING OF OAT (*AVENA SATIVA* L.) AND CANOLA (*BRASSICA NAPUS* L.) UNDER VARIABLE SEED PROPORTIONS ENHANCED FORAGE PRODUCTIVITY AND NUTRITIONAL QUALITY

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Abstract

Optimization of the proportionate share of component crops in mixed intercropping systems is vital for achieving the added advantage. This field study investigated the productivity of seed blended crops of oats and canola under different seed ratios (80:20, 60:40, 40:60, 20:80 and 50:50%), while their solitary crops were kept for comparison. The agronomic yield attributes, forage biomass and nutritional quality were taken as response variables. The yield attributes of oat in intercropping decreased significantly ($p \leq 0.05$) in comparison to the monoculture. Green forage yield and dry matter biomass of component crops decreased with the reduction of their seed proportion in mixtures. However, the maximum productivity (92 t ha^{-1}) of intercropping system was noted for oat and canola sown in 60:40 seed blending ratio, which was closely followed by 80:20 seed proportion. The crude protein ($p \leq 0.01$) and total ash ($p \leq 0.05$) contents of mixed forage were improved with increased share of canola seed in binary mixtures, while the pure stand of canola yielded the highest quality forage. However, seed blending of oat and canola in 60:40 seed proportion may be preferred owing to higher productivity (19%) and improved nutritional quality of mixed forage.

Key words: Animal nutrition, Component crops, Mixed intercropping, Planting geometry, Seed ratios.

Introduction

In Pakistan, dairy farming is an important sector of agriculture with more than 70 million heads of dairy animals (Iqbal *et al.,* 2017). The livestock feed comprising of low-quality roughages having sub-optimal concentration of essential minerals, vitamins and other nutrients reduce the productivity of milch animals (Iqbal *et al.,* 2015). Compared to roughages, forages provide high nutrition and energy and thus must be an integral constituent of feed (Iqbal *et al.,* 2017a). However, forages are in short supply during winters which result in underfeeding of dairy animals leading to a sharp decline in milk production (Iqbal *et al.,* 2018; Jamont *et al.,* 2013; Tahir *et al.,* 2003). Oat (*Avena sativa* L.) is one of the most important winter cereal forage but its forage yield and nutritional quality are not sufficient to meet the dietary requirement of large ruminants (Iqbal *et al.,* 2014). Canola (*Brassica napus* L.) is an oil seed crop having comparatively higher nutritional quality than cereal forages (Shoaib *et al.,* 2014) but yields lesser biomass (Reta-Sanchez *et al.,* 2016). Intercropping of high yielding cereals and protein-rich crops like canola is a feasible option to enhance forage yield and nutritional quality (Iqbal & Iqbal, 2015; Deak *et al.,* 2009). The nutritional quality of mixed forage was improved in oat and canola mixed seeding in 50:50 seed ratio (Shoaib *et al.,* 2014), but the biomass production was decreased (Ana *et al.,* 2017; Assefa & Ledin, 2001). In addition, the yield stability of intercropping system was enhanced with the addition of cereals like oat under diversified agro-climatic and soil conditions (Vasileva *et al.,* 2017; Deak *et al.,* 2009).

The binary mixtures of vetch and oat resulted in 78% higher biomass compared to wheat-vetch seed blended crop, while it was 63% higher to the mixed seeded crop of vetch and barley (Ansar *et al.,* 2010). Similarly, the seed mixture of oat with field peas was effective in producing 3.5 t ha^{-1} higher green forage than barley and pea seed blended crops (Jacobs & Wards, 2012). Another study reported that nutritional quality of mixed forage especially protein and fat content was improved in the mixed seeded crop of oat and vetch sown in equal seeding proportions (Rahetlah *et al.,* 2010). Furthermore, Kaut *et al.,* (2008) recorded higher dry matter (1 t ha^{-1}) in oat-wheat intercropping compared to their monocultures. In contrast, Aasen *et al.,* (2004) and Kara *et al.,* (2010) reported no yield advantage for oat and Triticale based intercropping systems.

To the best of our knowledge, experimental evidences are scarce on canola performance in intercropping with oat along with its suitability as a forage crop. Thus, it was hypothesized that canola intercropping with oat as seed blended crop may improve forage biomass and nutritional quality. The primary objective was to optimize the seeding ratios of oat-canola binary mixtures for better resource management. The ultimate goal was to develop a highly sustainable and productive oat based forage production system for improving the supply of nutritious forage during winter season.

Material and Methods

The present research regarding the productivity of oat-canola binary mixtures under varying seed proportions was conducted at the University of Agriculture, Faisalabad (31°25′45″N 73°4′44″E) during winter seasons of 2015-16 and 2016-17. The climate of Faisalabad is semi-arid according to Koppen climatic classification system that is characterized by hot humid summers and dry cooler winters, while its soil is classified as Haplic Yermosols by FAO (Naeem *et al.*, 2013). The soil of experimental site was analyzed for physico-chemical characteristics and it was found that the soil was sandy clay loam with pH of 7.4-7.6 (Table 1). The experimental soil was deficient in nitrogen and phosphorous, while it has also been reported to respond to potassium application (Iqbal *et al.*, 2016). The meteorological data for crop growing season is presented in Table 2, which was obtained from meteorological observation center located in the close proximity of experimental site.

The experiment was comprised of seven treatments i.e., oat alone, canola alone, 80% oat + 20% canola, 60% oat + 40% canola, 40% oat + 60% canola, 20% oat + 80% canola and 50% oat + 50% canola. The experiment was executed in a randomized complete block design (RCBD) and it was replicated thrice using the net-plot size of 6.3×15 m. There were 21 rows per experimental plot having the row-row spacing of 30 cm. The seeds of the oat (cv. S-2000) and canola (cv. Faisal-Canola) were sown with single row hand drill using a seed rate of 75 kg ha^{-1} and 5 kg ha^{-1} respectively. The recommended doses of nitrogen and phosphorus (elemental 92:50 kg ha^{-1} respectively) were applied in the form of urea and di-ammonium phosphate respectively. Half of the nitrogen along with full dose of phosphorous was applied as basal dose while the remaining half N was broadcasted with first irrigation at 17 days after sowing. All other agronomic practices except those under study were kept uniform for all the treatment combinations.

The emergence count was performed on complete emergence at 16 days after sowing. For measuring plant height at harvest, 15 plants were randomly selected and measuring tape was used to record height from base to tip of the highest leaf. For determining the green forage yield, the plants of both component crops were harvested in each plot and were weighted separated using a spring balance and then converted into tons per hectare (t ha^{-1}). For estimating the dry matter yield of canola and oat, plants of companion crops were chopped separately and then representative samples of 200 g of chopped biomass was dried at 65°C by placing it in an oven in the laboratory. Then, an electric balance was used to record the dry weight of each sample which was subsequently used to work out the dry matter percentage of intercrops. This dry matter percentage was further used to convert the fresh forage biomass to dry matter biomass yield.

The variance for interaction between the intercropping systems and year was recorded to be homogenous ($p<0.05$) and due to this non-significance, averaged data of two years were further statistically analyzed. Analysis of variance technique was employed using statistical software package "Statistix 8.1 version" and the treatments means were separated by orthogonal contrasts at 5% level of probability (Steel *et al.*, 1997).

Table 1. Physico-chemical analyses of experimental soil conducted before sowing at Faisalabad, Pakistan.

Soil characteristics	Recorded values	
Mechanical analysis	**2015-2016**	**2016-2017**
Sand (%)	54	57
Silt (%)	21.5	20
Clay (%)	24.5	23
Textural class	Sandy clay loam	Sandy clay loam
Chemical analysis	**2015-2016**	**2016-2017**
pH	7.4	7.6
EC (dSm^{-1})	1.71	1.64
Organic matter (%)	0.74	0.65
Total nitrogen (mg kg^{-1})	376.0	349.9
Available phosphorous (mg kg^{-1})	8.2	6.7
Available potassium (mg kg^{-1})	181.4	194.6

Table 2. Temperature (°C), precipitation (mm) and relative humidity (%) of experimental site during crop growing seasons of 2015-2016 and 2016-2017 along with last 10 years mean of meteorological data of Faisalabad (Pakistan).

Months	Temperature (°C)			Precipitation (mm)			Relative humidity (%)		
	2015-16	**2016-17**	**10 years mean**	**2015-16**	**2016-17**	**10 years mean**	**2015-16**	**2016-17**	**10 years mean**
September	37.8	38.0	37.5	23	16	20	64	61	59
October	33.3	34.4	33.9	9	13	5	51	49	46
November	29.0	29.3	28.0	7	3	2	45	42	41
December	22.4	22.8	22.1	10	18	8	43	40	40
Total/Mean	30.6	31.1	30.3	49	52	33	50.7	48.0	46.5

Table 3. Agronomic variables of germination count, plant height, tillers per plant, green forage yield and dry matter biomass of winter planted oat in monoculture and oat-canola mixed intercropping systems under irrigated and agro-climatic conditions of Faisalabad, Pakistan.

Treatments	Germination count (m^{-2})	Plant height (cm)	Tillers plant^{-1}	Green forage yield (t ha^{-1})	Dry matter biomass (t ha^{-1})
Oat alone	141.22a	141.96a	4.35d	77.86a	16.93a
Canola alone	-	-	-	-	-
80% Oat + 20 % canola	119.67b	121.04d	4.37d	53.15b	12.73b
60% Oat + 40 % canola	118.56b	132.73c	4.63cd	49.17c	10.12c
40% Oat + 60 % canola	99.22c	134.69bc	4.91c	28.11e	8.87d
20% Oat + 80 % canola	76.22d	133.05c	5.24b	17.42f	6.24e
50% Oat + 50 % canola	55.23e	136.29b	6.90a	34.82d	3.82f
Significance	*	**	*	**	**

Values having similar lettering do not vary at $p\leq 0.05$;*, significant at $P\leq0.05$; **, significant at $p\leq0.01$; Treatment × Year interaction was non-significant at $p\leq 0.05$

Results and Discussion

Germination count (m^{-2}), plant height (cm) and tillers per plant: The germination count of oat was enhanced with the increment of its share from 20 to 80% in mixed cropping; however, its highest germination count was recorded for the pure stand and the lowest for 20:80 seed proportion (Table 3). On an average, intercropping had a non-significant effect on germination count and the similar findings were reported by Iqbal *et al.,* (2017), who opined that cereal-legume intercropping in row replacement series did not affect the germination of component crops. It was concluded that germination count of intercrops was a genetic attribute and no evidence of adverse impact of intercropping was found as far as germination indices were concerned. Oat plant height was significantly ($p\leq0.01$) affected by seeding proportion of oat-canola mixtures. Higher seed proportion of oat in binary mixtures resulted in decreased plant height of forage oat. The maximum plant height was recorded from a pure stand of oat which was followed by oat sown in 50:50% seeding proportion with canola, while oat-canola sown in 80:20 seed proportion yielded the minimum plant height (Table 3). Furthermore, germination count and plant height were recorded to have a positive correlation with green forage yield of oat as illustrated by correlation analysis (Fig. 1). These findings are in corroboration with those of Iqbal *et al.,* (2016) and Juskiw *et al.,* (2000), who concluded that cereals plant height was reduced significantly in row and mixed intercropping systems with legumes owing to severe competition for growth resources. Likewise, comparatively lesser degree of competition among different crop species favored intercrops in attaining higher plant height compared to cereal-cereal intercropping (Sirydhorst *et al.,* 2008). The number of tillers per plant of oat was significantly ($p\leq0.05$) affected by seed blending ratios of oat and canola. Within oat mixtures, the tillers per plant decreased with increasing its seeding ratio in binary mixtures. The highest number of tillers per plant was recorded by the binary mixture of 20% oat + 80% canola which was statistically at par to 50% oat + 50% canola seed blended crop (Table 3). However, the number of tillers per plant of oat in monoculture (4.35) was quite lesser compared to reported by Ahmad *et al.,* (2008), who recorded eight tillers per plant.

Green forage and dry matter biomass of oat (t ha^{-1}): The effect of different seed proportions on green forage yield of oat was significant. Oat in monoculture produced the highest green forage yield (77.86 t ha^{-1}) and dry matter biomass (16.93 t ha^{-1}) as compared to binary crops of oat and canola (Table 3). Among seed blended crops, forage biomass production of oat was decreased with the decreased proportion of oat in binary mixtures as the lowest productivity of oat was recorded for oat and canola mixture sown in 20:80 seed proportion. The forage yield of oat was linearly correlated with mixed forage yield as depicted by correlation analysis (Fig. 1) which revealed the significant contribution of oat to the overall productivity of intercropping system. The biomass production of sole crops was also recorded to be on the higher side than binary mixtures by Juskiw *et al.,* (2000), who opined that comparatively lesser growth of component crops was observed in cereal-legumes intercropping systems owing to competition for growth resources and shading effect of taller cereals on dwarf legumes. Similar findings were also observed by Naeem *et al.,* (2013), where wheat and canola suffered huge loss of biomass in mixtures, but overall productivity was increased to a noticeable extent. The component crops having different agro-botanical characteristics increased the efficacy of farm applied resources in spatial and temporal dimensions and ultimately overall productivity was increased despite the decrease in the yield of component crops (Iqbal *et al.,* 2017).

Green forage and dry matter yield of canola (t ha^{-1}): Among binary mixtures, the solitary crop of canola resulted in the highest fresh forage biomass (61.22 t ha^{-1}) and dry matter biomass (14.90 t ha^{-1}), while the minimum intercrop productivity was recorded by canola sown in 20% seed proportion with oat (Table 4). Within the mixtures, the green forage yield and dry matter biomass of intercropped canola increased with its increased share in seed blended mixtures. These results are in line with the findings of Sirydhorst *et al.,* (2008), who concluded that forage productivity of intercrops witnessed a sharp decline in mixed intercropping systems as some intercrops were found to be more aggressive in acquiring growth resources which led to a sharp decline in forage yield of recessive intercrops. It was also noticed that short-statured intercrops recorded 21-49% biomass reduction in intercropping than their pure stands, but the corresponding decrease in cereals was relatively less (15-33%).

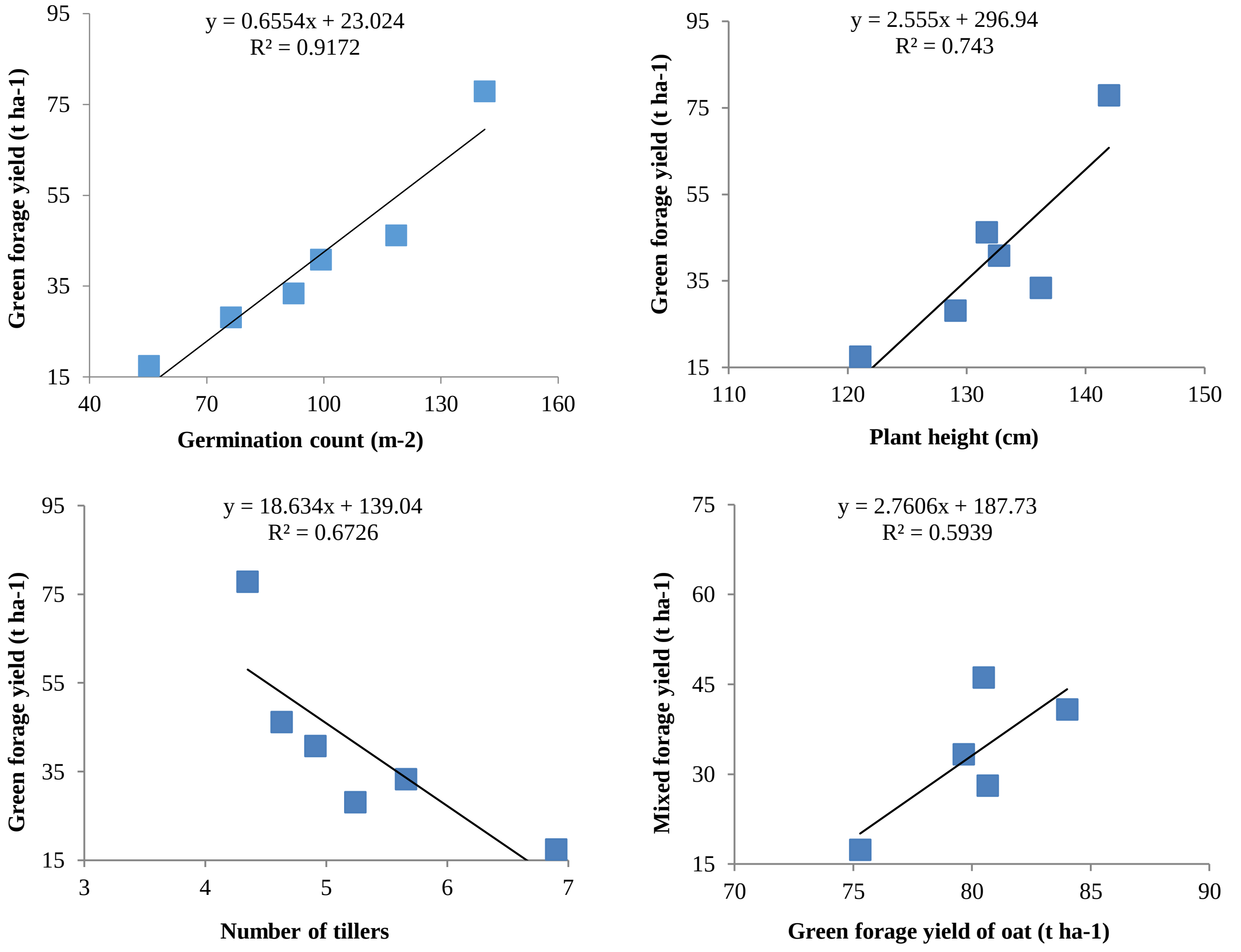

Fig. 1. Correlation of yield attributes with green forage yield of oat and mixed (oat + canola) forage yield of winter planted oat-canola mixed intercropping systems under irrigated and agro-climatic conditions of Faisalabad, Pakistan.

Table 4. Green forage yield and dry matter biomass of canola, mixed (oat + canola) green forage yield and mixed (oat + canola) dry matter biomass, crude protein and total ash of winter planted oat-canola mixed intercropping systems under irrigated and agro-climatic conditions of Faisalabad, Pakistan.

Treatments	Canola green forage yield (t ha^{-1})	Canola dry matter biomass (t ha^{-1})	Mixed green forage yield (t ha^{-1})	Mixed dry matter biomass (t ha^{-1})	Crude protein (%)	Total ash (%)
Oat alone	-	-	77.86d	16.93d	7.60d	9.03e
Canola alone	61.22a	14.90a	61.22f	14.90f	16.74a	13.72a
80% Oat + 20 % canola	34.32f	6.69d	87.47b	18.81b	9.25d	11.32d
60% Oat + 40 % canola	43.10e	8.28cd	92.27a	19.55a	11.65c	11.73c
40% Oat + 60 % canola	50.49c	9.82bc	85.31c	16.98d	13.36bc	12.39bc
20% Oat + 80 % canola	46.31d	11.12b	63.73e	17.14c	14.21b	12.50b
50% Oat + 50 % canola	57.87b	8.73c	85.98c	15.75e	12.78bc	12.06c
Significance	**	**	**	*	**	*

Values having similar lettering do not vary at $p \leq 0.05$;*, significant at $p \leq 0.05$; **, significant at $p \leq 0.01$; Treatment × Year interaction was non-significant at $p \leq 0.05$

Mix (oat + canola) green forage and dry matter yield (t ha^{-1}): The mixed forage yield is of the utmost importance as it indicates the advantage and efficacy of intercropping over mono cropping. Oat-canola mixed seeding in 60:40 seed blending ratio was instrumental in yielding 19% and 51% higher green forage compared to the monocultures of oat and canola respectively (Table 4). The lowest mixed green forage yield and dry matter biomass were recorded for the mixed seeded crop of oat and canola in the seed proportion of 20:80. Oat yielded green forage in higher quantity in intercropping with canola, thus mixed forage yield was decreased sharply with the decrease of oat's seed proportion in binary mixtures. Furthermore, oat recorded comparatively lesser decline in forage biomass than canola in mixtures which resulted in increased forage productivity with the increase of oat seed proportion. However, when oat seed proportion reached to 80%, forage yield was decreased probably owing to a greater degree of competition for nutrients and moisture among oat plants. The green forage yield of oat was recorded to be linearly correlated with mixed green yield (Fig. 1), which depicted that productivity of intercropping systems was increased with the increase of oat yield. The same sort of results was also observed by Tahir *et al.,* (2003), who concluded that although cereal-legumes intercropping resulted in comparatively lesser yield of component crops, but overall productivity was increased by 11-41% due to agro-botanical differences of component crops which diversified the use of farm applied resources in space and time dimensions. Furthermore, better weed control due to oat-pea intercropping systems resulted in better productivity than other intercropping systems (Lorin *et al.*, 2015; Lauk & Lauk, 2008).

Crude protein (%) and total ash (%): One of the major objectives of oat-canola mixed intercropping was to improve the protein and ash contents of mixed forage for boosting the productivity of large ruminants in terms of milk and meat production. Pure stand of canola gave the highest quality forage with the maximum crude protein and total ash contents. The contribution of canola in improving the crude protein of mixed forage was more prominent than oat and it was recorded that decreased concentration of canola resulted in reduced protein concentration. On an average, crude protein in mixtures was 9.25-14.21%, while the pure stands of canola and oat recorded 16.74 and 7.60% crude protein respectively (Table 4). In the previous studies of Szumigalski & Acker (2006), significantly higher protein content was obtained from the seed blended crops of wheat + canola as well as barley + annual rye grass as compared to their corresponding mono-crops. Statistically, the highest ash content was produced by canola alone while oat in monoculture had the lowest ash as compared to binary mixtures. Within mixtures, ash content increased as the seed proportion of canola was increased. On an average, oat and canola mixtures had 11.32-12.50% ash (Table 4). Canola was recorded to have considerably higher protein and ash contents and thus nutritional quality of mixed forage was improved with the increase of canola share in binary mixtures. These findings are in line with those of Banik *et al.,* (2000), who reported that Brassica intercrop was instrumental in boosting the nutritional quality as wheat was lower in agro-qualitative traits.

Conclusions

We had postulated the hypothesis that inclusion of canola as an intercrop with oat could boost forage productivity and nutritional quality of mixed forage. The findings of our field investigation proved to be in line with the hypothesis as forage yield and quality of mixed forage were substantially enhanced compared to the pure stands of oat and canola. Mixed seeding of oat and canola in 60:40 seed proportions remained superior to other binary mixtures as far as mixed green forage and dry matter biomass are concerned. On the other hand, seed blending of oat and canola in 20:80 seed proportion resulted in the maximum agro-qualitative traits of mixed forage. However, oat and canola seed mixing in 60:40 proportions could be preferred for yielding 19% higher biomass than their pure stands. Furthermore, it is suggested to conduct more cultivar specific investigations as binary mixtures of erect and spreading types of component crops may perform differently under varied agro-ecological conditions.

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