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FORAGE YIELD AS AFFECTED BY COMMON VETCH IN DIFFERENT SEEDING RATIOS WITH WINTER CEREALS IN POTHOHAR REGION OF PAKISTAN

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Abstract

In rainfed area of Pothwar, farmers and livestock producers have no option except to raise their animals on wheat straw and summer cereals stalk, which are poor in nutrients. In order to overcome the forage scarcity, two experiments were carried out during the year 2008-09 and 2010-11. In the first experiment, oat and vetch was grown in pure as well as in mix seeding ratio of 45:55, 30:70 and 15:85%. In the second experiment, the forage yield of common vetch and winter cereals: oat, wheat and barley in pure and in three different seeding ratios of 13:87, 25:75, 50:50 as well as in pure stands of vetch and cereals were studied to find out the best yielding seeding ratio. The vetch-oat seeding ratio of 30:70% ratio produced higher forage yield under rainfed condition while the vetch-cereal seeding ratio of 25:75 performed better in terms of green as well as dry matter production. The vetch-oat, vetch-barley and vetch-wheat in 25:75 seeding ratio resulted in 1.06, 1.04 and 1.10 LER values which indicated the advantage of vetch-cereal 25:75 seeding ratio over pure stand. Vetch-oat, vetch-barley and vetch-wheat in 25:75 seeding ratio resulted in 6.2%, 4.8% and 10.0% higher water use efficiency (WUE) and an average 16.3%, 16.8% and 23.9% higher photosynthetic active radiation (PAR) values than their respective pure stands, and produced 7, 4 and 5% higher green forage yield respectively, compared to their respective pure stand.

Introduction

Livestock sector has emerged as priority sector recently in policy formulation as it directly contributes towards human livelihood especially poor farmers of rural community. Livestock has been subsistence sector dominated by small land holders to meet their domestic needs of milk, meat and to earn income for their daily expenses. In the rural areas, livestock is considered as a more secure source of economy for small and landless farmers. It has become important source of income generation through self-employment and to meet emerging day to day emergencies in rural areas. The sector is mitigating income variability in rural economy as crop sector is more vulnerable to uncertain weather vagaries in rainfed areas. Livestock is considered as an important indicator of wealth status of a family and is still best option for poverty alleviation among rural communities to improve and uplift the socio-economic conditions in remote rural areas of the country. The livestock accounts for approximately 55.1 percent of the agriculture value added and 11.5 percent to GDP (Anon., 2011).

In addition to scarcity of water, poor soil fertility and mono-cropping cereal systems, needs have badly affected the productivity of agricultural crops in rainfed areas and the forage crops have no exception for sustainability (Khan *et al*., 2012). In Pothowar region, farmers usually use wheat and its straw to feed their livestock. Barley and oat too have shown potential as forage crop in rainfed Pothowar region (Ansar *et al*., 2010). Among these crops, barley is more tolerant to dryness, poor soils, salinity, and usually gives higher grain yield than oat and wheat. Grains as well as straw of these crops are important source of food for humans and feed for animals, respectively. Feed legumes have not been widely adopted by farmers in the Pothowar region (Nadeem *et al.*, 2010).

In winter leguminous crops, common vetch (*Vicia sativa* L.) is one that is mostly used as mix or intercropping with wheat, oat and barley in the mediterranean countries. Common vetch, belonging to the family Fabaceae needs a frame due to its climbing growth habit and provides nitrogen to companion cereal crop. It is usually grown in mixtures with grain cereals for hay or forage production (Anil *et al*., 1998). Other benefits of vetch in mixtures include greater uptake of water and nutrients, enhanced weed suppression, and increased soil conservation (Vasilakoglou *et al*., 2005). It is therefore considered as versatile forage legume (Jones & Arous, 1999).

In rainfed regions of Pothowar, fertility status of the soils is low, particularly with regards to organic matter and farmers are using wheat and brassica as green fodder in winter and maize / sorghum or millet in summer months. These crops are exhaustive in nature and continuously depleting heavy nutrients from the soil. The use of inorganic nitrogenous fertilizers is very restricted because of low rainfall for agricultural crops especially fodder crops in rainfed areas. So, there is dire need of time to include legumes with cereals for forage productivity so that livestock farming could be continued on sustained basis (Parveen *et al*., 2001). The traditionally used wheat straw for livestock is not a rich source of nutrition for animals and thus health and productivity of livestock is badly affected. Studies already conducted in the department have shown that vetch performed better under Pothowar conditions than other winter legumes (Anwar *et al.*, 2010).

In present study, efforts were made to explore different common vetch-cereal seeding ratios to reap more benefits in terms of forage yield and to minimize the input expenditures in rainfed region of Pothowar.

Materials and Methods

A two year field study was carried out independently; one at farmer ‘s field and other at Pir Mehr Ali Shah-Arid Agriculture University Research Farm Chakwal Road Rawalpindi during 2008-09 and 2010-11 to ascertain the forage yield as affected by common vetch in different seeding ratios with winter cereal crop in Pothowar region of Pakistan. Daily maximum and minimum temperature (^{o}C) and rainfall (mm) data recorded during study period are presented in Fig. 1.

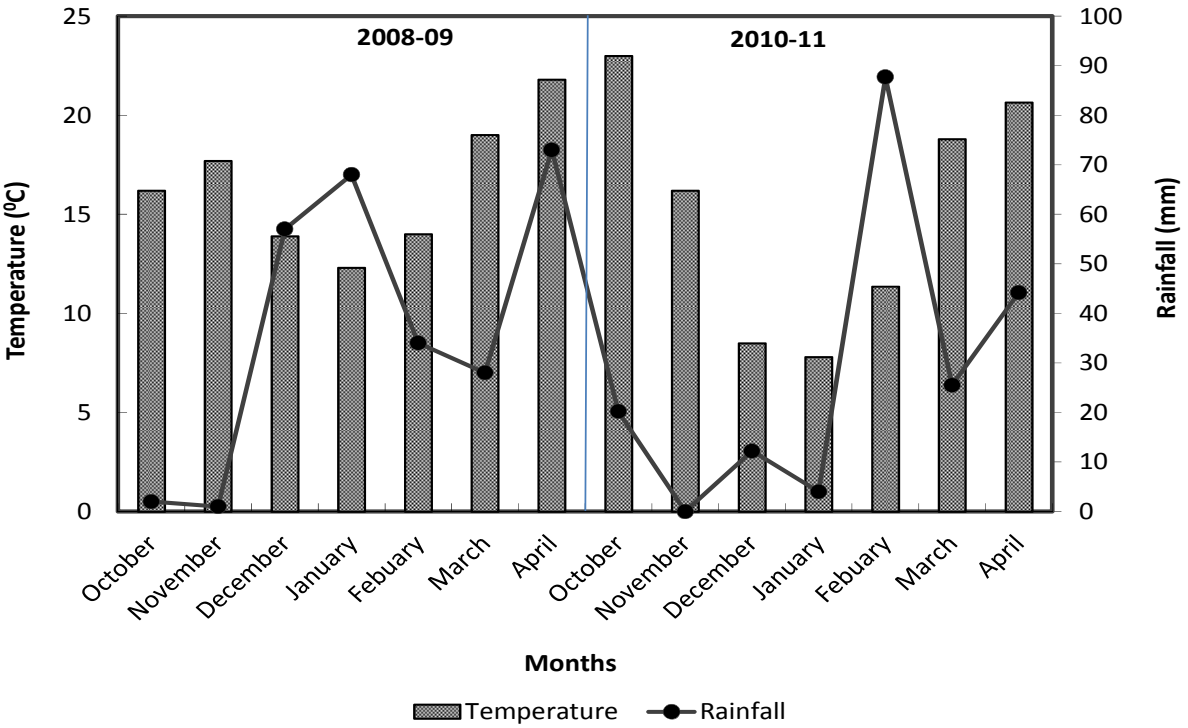

Fig. 1. Rainfall (mm) and Temperature (^{0}C) data recorded during crop growth of 2008-09 & 2010-11. Source: Soil & Water Conservation Research Institute, Chakwal.

Soil samples were taken from the soil depth before sowing and after harvesting during both the years. Soil was sandy loam having pH (7.5 and 7.4), electrical conductivity of 0.86 and 0.85 ds cm^{-1}, organic matter of 0.76 and 0.78 % and nitrate nitrogen (1.6 and 1.9 ppm) before and after sowing, respectively, during 2008-09. Similarly during 2010-11, pH (7.6 and 7.6), electrical conductivity of 0.52 and 0.53 ds cm^{-1}, organic matter of 0.63 and 0.68% and nitrate nitrogen (1.5 and 2.0 ppm) before and after sowing. The study comprised of two sets of experiments. Both the experiments were sown with a single row hand drill in 30 cm apart rows. In the first experiment, mixture of two crops i.e., vetch (Languedock) and oat (PD_2-LV_{65}) were used, with 45:55, 30:70 and 15:85 seeding ratio, respectively. Phosphorus and nitrogen fertilizer were applied @ 100 and 25 kg ha^{-1}, in the form of DAP and urea respectively, in all treatments. In second experiment, the treatments were pure of stand Languedock, C-591, PD_2-LV_{65}, and Jao-86. Varieties of Vetch, Wheat, Oat and Barley, respectively, were sown at the seed rates of 50, 100, 80 and 75 kg ha^{-1}, while in mixture each of the species was mixed with vetch in 25:75, 50:50 and 13:87 seeding ratio. For mixture, the seed of crops was mixed well to homogenize the seeds before sowing in ratios as per schedule of the treatments on weight basis. Randomized complete block design was used with three replications during both the years. First experiment comprised five while 2nd experiment consisted of thirteen treatments of vetch-cereal in pure as well as mix stand in weight: weight ratios (Tables 1 & 2).

The net plot size of each treatment was 15 m^2 and to separate plots from each other, a buffer zone of 60 cm was maintained. In the first field study, the plant samples were taken from randomly selected area of one m^2 from each plot at different growth stages like tillering (65 DAS), pre-heading (110 DAS) and 50% heading stage (130 DAS) to determine the green forage and dry matter yield. Crop growth rate was calculated by using the formula as described by Beadle (1985) between different crop growth stages. Land equivalent ratio was calculated by using the formula as proposed by Shobeiri *et al*., (2010). The plant samples were taken from randomly selected one m^2 area from each plot to determine the green forage and dry matter yield and then converted into t ha^{-1}. Five plants were selected at random from each plot to record number of leaves and tillers plant^{-1}. Photosynthetic Active Radiation was recorded from 2nd experiment using IRGA apparatus (LCA-4) in each treatment. Two leaves of each common vetch and cereal crops from each plot were placed in the leaf chamber of the IRGA apparatus on a bright sunny day and the reading was recorded when it became stable. Water use efficiency was calculated by formula given by Chen *et al*., (2003). Partial budget analysis was done to calculate gross field benefits (*GBf*) as follows:

$GB_f = P_f \times Y_{adj}$

P_f: output's field price; **Y_{adj}:** adjusted yield of a treatment

The NB is calculated as follows.

NB: GB_f - TCV

All the data obtained were subjected to analysis of variance using MSTAT-C. Analysis of variance technique was employed to test the overall significance of the treatments. Least significance difference test at 5% probability level was used to compare the mean treatments (Steel *et al*., 1997).

Table 1. Details of treatments of experiment carried out at farmer's field during the year 2008-09

Treatment No.	Crop	Variety	Stand state	Ratio (W/W)
T_1	Vetch + Oat	----------	Mix Stand	45:55
T_2	Vetch + Oat	----------	Mix Stand	30:70
T_3	Vetch + Oat	----------	Mix Stand	15:85
T_4	Oat	PD_2-LV_{65}	Pure Stand	100:00
T_5	Vetch	Languedock	Pure Stand	00:100

Table 2. Details of treatments of experiment carried out at University Research farm Chakwal Road Rawalpindi during 2010-11

Treatment No.	Crop	Variety	Stand state	Ratio (W/W)
T_1	Oat	PD_2-LV_{65}	Pure Stand	100:00
T_2	Barley	Jao-86	Pure Stand	100:00
T_3	Wheat	C-591	Pure Stand	100:00
T_4	Vetch	Languedock	Pure Stand	100:00
T_5	Vetch: Oat	----------	Mix Stand	13: 87
T_6	Vetch: Oat	----------	Mix Stand	25: 75
T_7	Vetch: Oat	----------	Mix Stand	50: 50
T_8	Vetch: Barley	----------	Mix Stand	13: 87
T_9	Vetch: Barley	----------	Mix Stand	25: 75
T_{10}	Vetch: Barley	----------	Mix Stand	50: 50
T_{11}	Vetch: Wheat	----------	Mix Stand	13: 87
T_{12}	Vetch: Wheat	----------	Mix Stand	25: 75
T_{13}	Vetch: Wheat	----------	Mix Stand	50: 50

Results and Discussion

Green fodder yield (t ha^{-1}): Data regarding green fodder yield recorded during 2008-09 and 2010-11 presented in the Tables 3 & 4 showed statistically significant difference among treatment means. In the first year of experiment, vetch + oat with 30:70 seeding ratio produced the highest green fodder yield of 20.85 t ha^{-1} followed by vetch + oat with 15:85 seeding ratio of 15.26 t ha^{-1} and vetch + oat with 45:55 seeding ratio (13.27 t ha^{-1}). The treatments and growth stages means showed that vetch + oat mixture with 30:70 seeding ratio resulted in better performance than pure stands of vetch and oats. These results are in line with the findings of Tuna & Orak (2007) who reported that mixtures were more productive than pure vetch sowing. They also quoted in another study that the highest herbage yield was obtained from mixture of 25% vetch + 75% oat while the lowest herbage yield from pure stands of vetch. Data recorded at different growth stages showed significant differences among one another during this study. With the advancement of growth stages, green fodder yield increased progressively. The maximum green fodder yield was recorded at 50% heading and the lowest at tillering stage. The interaction between treatments and growth stages showed statistically significant results. The maximum green fodder yield was obtained from 30 % vetch + 70% oat at 50% heading stage and minimum green fodder yield was obtained by vetch crop in pure stand at tillering stage.

In second experiment, vetch-cereal combinations gave the highest green forage yield of 22.30 t ha^{-1} from vetch 25 + 75 oat seeding ratio and the lowest of 16.98 t ha^{-1} by vetch-barley 50:50 seeding ratio. In vetch-cereal combinations of both oat and barley showed similar trend to each other resulting in the highest green forage yield of 22.30 t ha^{-1} and of 19.74 t ha^{-1}, respectively, obtained by vetch-cereal seeding ratio of 25:75, whereas, the lowest green forage yield of 18.36 t ha^{-1} and 16.98 t ha^{-1} was obtained by vetch-cereal 50:50 seeding ratio of oat and barley, respectively. In vetch-wheat combinations, the highest green forage yield of 18.80 t ha^{-1} was obtained in 25:75 seeding ratio followed by 17.97 t ha^{-1} in 13:87 seeding ratio of the same crop combination and lowest green forage yield of 17.42 t ha^{-1} was obtained by 50:50 seeding ratio. Among all the vetch-cereal seeding ratio combinations, vetch-oat yielded 13.61% higher green forage yield than vetch-barley combinations which in turn produced 3.53% higher green forage yield than vetch-wheat combinations. This could be due to relatively higher leaf area plant^{-1}, plant height and number of tillers achieved by oat crop. Among all the seeding ratios, it has been observed clearly that 25:75 seeding ratio resulted in higher green forage yield than rest of the seeding ratios investigated in this study. It has also been observed that in vetch-cereal combinations, with the increase of legume seed ratio from 13% to 25%, resulted in increased green forage yield but further increase of vetch in seeding ratio from 25% to 50% resulted in decrease in green forage yield which indicated the benefits of the appropriate common vetch with winter cereal seeding ratio. In seeding combinations of vetch with oat, barley and wheat in 25:75 seeding ratio, produced the highest GFY than rest of seeding ratios, produced 4, 5 and 7 % higher green forage yield, respectively than their respective cereals in pure stands. Nadeem *et al*., (2010) conducted research on

performance of winter legumes-cereal forage mixtures in 50:50 seeding ratios and their pure stand at different growth stages under rainfed conditions of Pothowar and found the highest green fodder yield from vetch-oat 50:50 seeding ratio in comparison with vetch-barley and vetch-wheat combinations sown with same seeding ratios. Caballero *et al*., (1995) reported that mixtures of common vetch with oat produced 34 % more forage yield than common vetch alone, but 57 % less than monoculture oat. However, Giacomini *et al*., (2003) found that yield of mixtures was similar to that of oat and greater than that of mono-culture of common vetch.

In pure stands, during 2008-09, the highest green fodder yield was recorded by oat (12.46 t ha^{-1}) and the lowest by vetch (5.58 t ha^{-1}) while during 2010-11, the highest green forage yield in pure stands was obtained by oat crop of 21.49 t ha^{-1}, followed by barley of 18.78 t ha^{-1}, wheat of 17.52 t ha^{-1} and the lowest one of 11.13 t ha^{-1} was obtained by vetch crop.

Table 3. Green fodder yield (t ha^{-1}) of oat-vetch mixture at different growth stages

Treatments	Growth stages			
	Tillering (65 DAS)	Pre- heading/ (110 DAS)	50% Heading (130 DAS)	Means
45% vetch + 55% oat	5.50 fg	10.10 ef	22.97 b	**13.27 AB**
30% vetch + 70% oat	5.77 fg	24.27 b	32.51 a	**20.85 A**
15% vetch + 85% oat	3.90 g	15.00 cd	26.87 b	**15.26 B**
Oat (pure stand)	5.73 fg	13.76 cde	17.87 c	**12.46 C**
Vetch (pure stand)	1.50 g	3.27 g	10.97 de	**5.58 D**
Means	4.48 C	13.28 B	22.69 A	

LSD (P=0.05) for treatments mean (T) = 2.690; LSD (P=0.05) for harvest stages (HS) = 2.084; LSD (P=0.05) for T x HS = 4.660

Table 4. Green and dry matter yield, land equivalent ratio, water use efficiency and photosynthetic active radiation of different vetch-cereal seeding ratios and their pure stands recorded during the winter 2010-11

Crops	Seeding ratio	GFY (t ha^{-1})	DMY (t ha^{-1})	LER	WUE	PAR
Oat	100	21.49 a	7.14 a	-	13.32 a	984.3 c
Barley	100	18.78 cd	5.94 c	-	11.65 bc	1052 bc
Wheat	100	17.52 de	5.99 c	-	10.60 d	1053.7 bc
Vetch	100	11.13f	3.48 d	-	6.91 e	937.7 c
Vetch: Oat	13: 87	21.14 ab	6.90 ab	0.99 cd	13.27 a	1103.3 abc
Vetch: Oat	25: 75	22.30 a	7.25 a	1.06 ab	14.14 a	1164.7 abc
Vetch: Oat	50: 50	18.36 cde	5.80 c	0.85 e	11.38 bcd	1165.7 abc
Vetch: Barley	13: 87	18.35 cde	5.82 c	0.98 d	11.37 bcd	1395.7 a
Vetch: Barley	25: 75	19.74 bc	5.93 c	1.04 abc	12.23 b	1191.3 abc
Vetch: Barley	50: 50	16.98 e	5.80 c	0.90 e	10.54 d	1101 abc
Vetch: Wheat	13: 87	16.97 e	5.67 c	0.99 cd	10.52 d	1065.3 abc
Vetch: Wheat	25: 75	18.80 cd	5.69 c	1.10 a	11.66 bc	1320.7ab
Vetch: Wheat	50: 50	17.42 de	5.65 c	1.02 bcd	10.80 cd	1099.7 abc
LSD		0.681	0.870	0.06	0.88	333.23

GFY, green forage yield; **DMY,** dry matter yield; **LER,** land equivalent ratio; **WUE,** water use efficiency; **PAR,** photosynthetic active radiation.

Dry matter yield (t ha^{-1}): Data regarding dry matter yield recorded during this study, presented in the Tables 4 & 5 showed statistically significant differences among treatments. During 2008-09, maximum dry matter yield of 6.86 t ha^{-1} was produced by T_2 followed by T_3 (4.58 t ha^{-1}) and T_1 (3.82 t ha^{-1}). The treatments and growth stages means showed that 30% vetch + 70% oats mixture ratio gave better performance than pure stands of vetch and oats. These findings are similar to the results of Ansar *et al*., (2010) who worked on the cereal- vetch mixtures for forage yield and quality under rainfed conditions of Pothwar and recorded that vetch-oat mixtures produced the highest dry matter yield in comparison with any other vetch-cereal mixtures. Similarly in another research study conducted on non-traditional legume mixtures with oats and vetch + oats mixture produced better forage yield in comparison with oat + senji and oats + medic mixtures (Anwar *et al.,* 2010). In general, the mixtures produced higher forage yield than the pure stands. Tuna & Orak (2007) also found high dry matter yield in oat-vetch mixture. Similar results were also reported by Assefa & Ledin (2001) in which DM forage yield of pure vetch, oat and mixture forage was 4.3, 7.6 and 7.3 t ha^{-1}, respectively. Data recorded of dry matter yield at different growth stages showed the significant difference with each other. With the advancement of growth stages, dry matter yield increased progressively. The maximum dry matter yield was recorded at 50% heading during this study and low at tillering stage. The interaction between treatments and growth stages showed significant results. The maximum dry matter yield was observed in 30% vetch

+ 70% oat seeding ratio at 50% heading stage and minimum yield was obtained by vetch crop in pure stand at tillering stage.

In 2nd year (2010-11) experiment, maximum dry matter yield of 7.25 t ha^{-1} was obtained by vetch-oat 25:75 seeding ratio and the lowest of 5.65 t ha^{-1} by vetch-wheat seeding ratio of 50:50. In different vetch-oat seed ratios tested in this study showed that the highest dry matter yield of 7.25 t ha^{-1} was obtained by vetch-oat seeding ratio of 25:75 followed by vetch-oat seeding ratio of 13:87 with dry matter yield of 6.90 t ha^{-1} and the lowest by seeding ratio of 50:50 with dry matter yield of 5.80 t ha^{-1}. The mixtures of different vetch legume with barley seeding ratios also showed the same trend as shown by vetch-oat seeding ratios. The maximum dry matter yield of 5.93 t ha^{-1} was attained by 25% vetch + 75% barley seeding ratio followed by 5.82 t ha^{-1} DM yield by 13% vetch + 87% barley seeding ratio and the lowest DMY of 5.80 t ha^{-1} was obtained by 50:50 seeding ratio of both the crops. In vetch-wheat different seeding ratio, the highest dry matter yield of 5.69 t ha^{-1} was recorded from 25% vetch + 75% wheat seeding ratios, followed by 13% vetch + 87%wheat seeding ratio with DMY of 5.67 t ha^{-1} and minimum DMY of 5.65 t ha^{-1} was obtained by vetch-wheat 50:50 seeding ratio. Similarly, Bedoussac & Justes (2010) found 20% and 120% higher dry matter yield in pea-wheat inter-crop than wheat and pea mono-crop, respectively. Kocer & Albayrak (2012) reported that pea-oat and pea-barley mixtures at 65:35 seeding ratio produced higher dry matter yield than their pure stands.

In pure stand treatments, maximum dry matter yield of 3.74 and 7.14 t ha^{-1} was produced by oat crop and the lowest by vetch of 1.54 and 3.48 t ha^{-1} during the year 2008-09 and 2010-11, respectively.

Land equivalent ratio: Land equivalent ratio (LER) is the relative land area under sole crops that is required to produce the yields achieved in inter-cropping. Data regarding land equivalent ratio presented in Tables 4 & 6 showed the significant differences among the growth stages in first year experiment. The highest LER value of 1.47 was recorded in 30% vetch + 70% oat seeding ratio followed by 15% vetch + 85% oat and 45% vetch + 55% oat seeding ratio with 1.23 and 1.22 LER values, which means that 47, 23 and 22% more land was required to produce similar yield to pure stands. Similar results were reported by Shobeiri *et al*., (2010) who conducted an experiment to determine the best mixture combination of legume and cereal for forage production under the agro-ecological conditions of Iran and reported that mixture treatments have LER more than one. The interaction among the treatment means and growth stages showed statistically significant differences. The maximum LER of 1.94 was found in 30% vetch + 70% oat at 50% heading stage while minimum LER of 0.89 was recorded in 45% vetch + 55% oat seeding ratio at tillering stage.

Table 5. Dry matter yield (t ha^{-1}) of oat-vetch mixture at different growth stages

Treatments	Growth stages			
	Tillering (65 DAS)	Pre- heading (110 DAS)	50% Heading (130 DAS)	Means
45% vetch + 55% oat	1.83 fg	3.07 ef	6.56 bc	**3.82 B**
30% vetch + 70% oat	1.92 fg	7.37 b	11.30 a	**6.86 A**
15% vetch + 85% oat	1.30 g	4.57 de	7.87 b	**4.58 B**
Oat (pure stand)	1.91 fg	4.20 de	5.10 cd	**3.74 B**
Vetch (pure stand)	0.50 g	1.00 g	3.13 ef	**1.54 C**
Means	**1.49 C**	**4.04 B**	**6.79 A**	

LSD (P=0.05) for treatments mean (T) = 0.9814; LSD (P=0.05) for harvest stages (HS) = 0.7602; LSD (P=0.05) for T x HS = 1.70

Table 6. Land equivalent ratio (LER) of different oat-vetch mixtures at different growth stages

Treatments	Growth stages			
	Tillering (65 DAS)	Pre-heading (110 DAS)	50% Heading (130 DAS)	Means
45% vetch + 55% oat	0.89	0.99	1.77	**1.22 A**
30% vetch + 70% oat	1.43	1.05	1.94	**1.47 A**
15% vetch + 85% oat	1.11	1.10	1.48	**1.23 A**
Means	1.15 B	1.05 B	1.73 A	

LSD (P=0.05) for treatments mean (T) = 0.2567; LSD (P=0.05) for harvest stages (HS) = 0.2587

In second study, mixture treatments of oat crop with vetch the highest LER value of 1.06 was obtained by 25% vetch + 75% oat seeding ratio followed by 0.99 LER in 13% vetch + 87% oat seeding ratio and minimum LER value of 0.85 was found in vetch-oat 50:50 seeding ratio. This indicated that the increase of vetch more than 25% reduced the tonnage of the forage and 15% extra land is required to produce the forage equal to the pure stand of the mixture crop. Vetch-Barley too, showed the similar results to that of vetch-oat seeding ratios. 25% vetch + 75% barley seeding ratio resulted in the highest LER value of 1.04 which is higher than 1 followed by 13% vetch + 87%

barley seeding ratio with LER value of 0.99 which is almost equal to the pure stand yield and the lowest LER value of 0.90 was obtained by vetch-barley (50:50) seeding ratio indicating 10% decrease in forage yield or 10% more land is required to produce the forage equal to the pure stand of mixture crops. In mixture treatments of vetch with wheat crop, the maximum mean value of 1.10 for LER was found in vetch-wheat seeding ratio of 25:75 followed by vetch-wheat (50:50) seeding ratio with 1.02 LER and the lowest LER value of 0.99 was achieved by vetch-wheat 87:13 seeding ratio.

25% vetch + 75% oat seeding ratio resulted in 6 % more LER value than oat pure stand. Similarly, vetch-barley and vetch-wheat 25:75 seeding ratios resulted in 4 % and 10 % higher LER than their respective pure stands which indicates the benefit of common vetch-cereal combinations as higher LER value was calculated than 1 indicating the clear advantage of vetch-cereal mixtures due to better land utilization and better use of the environmental resources for plant growth. Banik *et al*., (2006) found that in case of pea-cereal mixtures 80:20, and pea-triticale 60:40 mixture, total LER value was higher than 1, which showed a yield advantage of intercropping over pure stands. LER values of these mixtures were 1.08-1.19, in other words 8-19% more land area would be required by a mono-cropping system to equate the yield of intercropping system, indicating greater land use efficiency of intercrops than mono-crops (Agegnehu *et al.,* 2006). These findings are in agreement with those of Bedoussac & Justes (2010) who reported a mixed stand advantage with pea-wheat mixtures which was different at the different growth stages. Also, Dhima *et al*., (2007) found LER values 1.05-1.09 in mixtures of common vetch with different grain cereals such as wheat, triticale, barley and oat.

Crop growth rate (g m^{-2} day^{-1}): Crop growth rate (CGR) is an increase in dry matter per unit land over time. Data regarding crop growth rate presented in Table 7 showed significant differences among treatments. The maximum crop growth rate of 15.71 g m^{-2} day^{-1} was attained by 30% vetch + 70% oat crop followed by 15% vetch + 85% oat of 13.9 g m^{-2} day^{-1}, oats as pure stand resulted CGR by (9.71 g $m^{-2}day^{-1}$) followed 45% vetch + 55% oat of 8.32 g $m^{-2}day^{-1}$ and the lowest by vetch of 7.41 g m^{-2} day^{-1}**.** These findings are in accordance with Alam & Haider (2006).

Table 7. Crop growth rate (CGR) of different oat-vetch mixtures at different growth stages

Treatments	Growth stages			
	Tillering (65 DAS)	Pre-heading (110 DAS)	50% Heading (130 DAS)	Means
45% vetch + 55% oat	2.31 hi	2.43 hi	4.89 gh	**8.32 D**
30% vetch + 70% oat	2.81 hi	7.60 ef	6.31 fg	**15.71 A**
15% vetch + 85% oat	2.44 hij	2.69 hij	6.16 fg	**13.90 B**
Oat (pure stand)	2.48 hij	2.58 hij	5.97 fg	**9.71 C**
Vetch (pure stand)	1.78 ij	0.13 j	2.58 hij	**7.41 D**
Means	**2.37 D**	**2.94 C**	**6.21 B**	

LSD (P=0.05) for treatments mean (T) = 1.281; LSD (P=0.05) for harvest stages (HS) = 0.968; LSD (P=0.05) for T x HS = 2.563

Water use efficiency (WUE): Water use efficiency (WUE) is ratio of forage yield to the volume of water consumed in mm during crop growth season. Data regarding water use efficiency showed statistically significant differences among treatments as presented in Table 4. In pure stand treatments, maximum water use efficiency of 13.32 was found in treatment where oat crop was sown followed by barley with 11.65 WUE and wheat crop with 10.60 WUE whereas minimum value for water use efficiency of 6.91 was recorded from pure stand of vetch crop.

In mixture treatments, maximum value for water use efficiency value of 14.14 was attained by 25% vetch + 75% oat seeding ratio and the minimum value of 10.54 was attained by vetch-barley 50:50 seeding ratio. In vetch-oat seeding the highest value for WUE of 14.14 was recorded in 25:75 seeding ratio and the lowest value of 11.38 in 50:50 seeding ratio of vetch-oat mixture. Vetch-barley seeding ratio of 25:75 attained maximum value for WUE of 12.23 and minimum value of 10.54 WUE was obtained by vetch-barley seeding ratio of 50:50. Higher value for WUE in mixture treatments could be the result of lesser leaf area of vetch crop. Hence, lesser leaf area transpired less water that is why less WUE was recorded and water within appropriate combination with nutrients was utilized for crop growth and thus resulted in higher final forage yield. The results of current study are in correspondence with the findings of Pala *et al*., (2007) who reported higher value for WUE in vetch-wheat cropping system in comparison with wheat-fallow-wheat.

Photosynthetic active radiation (PAR): Data regarding photosynthetic active radiation (PAR), presented in Table 4, showed significant differences among different treatments. In pure stand treatments, maximum value for photosynthetic active radiation value of 1053 µ mole m^{-2} s^{-1} was found in wheat pure stand followed by barley pure stand with PAR value of 1052.00 µ mole m^{-2} s^{-1} and oat pure stand plants with PAR value of 984.3 µ mole m^{-2} s^{-1}; whereas, the minimum PAR value of 937.7 µ mole m^{-2} s^{-1} was obtained in vetch pure stand. Results of the current study are contradictory to the findings of O'Connell *et al*., (2004) who reported more PAR in pea legume plants than wheat cereals crop plants. The difference may be the result of different legume crop used in the investigation.

Perusal of Table 8 indicated positive association between forage yield with dry matter yield, land equivalent ratio, water use efficiency and photosynthetic active radiation. All possible combinations such as green fodder yield, dry matter yield, land equivalent ratio (LER), water use efficiency and photosynthetic active radiations were found to be positively correlated with one another. Among the relationships worked out between different variables, green fodder yield and water use efficiency (r: 1.00) showed highly significant and positive relationship between them, while contradictory results were reported by Achakzai & Taran (2011).

Economic analysis

Partial budgeting: Partial budgeting is a planning and decision-making framework used to compare the costs and benefits of alternatives available to farm business. Table 9 presents separate partial budgets for varieties of vetch, oat, wheat and barley to calculate the net benefit of each as a pure stand and their different mixture seeding ratios. The results of the partial budget indicated that the use of 25% vetch + 75% oat seeding ratio resulted in higher net benefit of 76175 followed by 13% vetch + 87% oat with net benefits of 72278. Similar trend of net benefit was observed in vetch + barley and vetch + wheat seeding ratios. The highest net benefits were obtained in 25% common vetch with 75% either oat, barley or wheat followed by 13% common vetch + 87% seeding ration in either cereal crop while the lowest net benefit was recorded by 50% vetch + 50% cereal of either crop. In pure stands oat resulted high net benefit followed by wheat and barley which were at par with each other and the lowest by common vetch crop. The present results are in accordance with that of Shah *et al*., (2012) and Usmanikhail *et al*., (2012).

Table 8. Correlation among green fodder yield with dry matter yield, land equivalent ratio, water use efficiency and photosynthetic active radiation of different vetch-cereal seeding ratio and their pure stands

	GFY	DMY	LER	WUE
DMY	0.97			
LER	0.42	0.23		
WUE	1.00	0.96	0.41	
PAR	0.32	0.18	0.28	0.32

GFY, green forage yield; **DMY,** dry matter yield; **LER,** land equivalent ratio; **WUE,** water use efficiency; **PAR,** photosynthetic active radiation.

Table 9. Partial budget analysis of different vetch-cereal seeding ratio and their pure stands

Treatment	Crop	Seeding ratio	Adj. Yield	Field Price	Gross Field	Cost of Seed	TCV	NB
T1	oat	100	6069	12	72828	4000	4000	68828
T2	barley	100	5049	10	50490	3750	3750	46740
T3	wheat	100	5091.5	10	50915	4000	4000	46915
T4	vetch	100	2958	15	44370	3750	3750	40620
T5	V + O	13: 87	5865	13	76245	3967.5	3967.5	72278
T6	V + O	25: 75	6162.5	13	80112.5	3937.5	3937.5	76175
T7	V + O	50: 50	4930	13	64090	3875	3875	60215
T8	V + B	13: 87	4947	11	54417	3750	3750	50667
T9	V + B	25: 75	4505	11	49555	3750	3750	45805
T10	V + B	50: 50	4930	11	54230	3750	3750	50480
T11	V + W	13: 87	4819.5	11	53014.5	3967.5	3967.5	49047
T12	V + W	25: 75	4836.5	11	53201.5	3937.5	3937.5	49264
T13	V + W	50: 50	4802.5	11	52827.5	3875	3875	48952.5

TCV, total cost vary; **NB,** net benefits

Conclusions

On the basis of two years field investigations, 25% common vetch + 75% oat seeding ratio produced better forage yield, CGR, LER, and water use efficiency observed in barley and wheat seeding ratios with common vetch under rainfed conditions of Pothwar. The combination of common vetch with winter cereals holds several benefits to small land holders of rainfed region of Pothowar. Therefore, farmers and livestock owners are advised to mix 25-30% common vetch seed with winter cereals to obtain higher forage yield for their livestock to boost livestock production in rainfed areas.

References

Achakzai, A.K.K. and S.A. Taran. 2011. Effect of seed rate on growth, yield component sand yield of mash bean grown under irrigated conditions of arid uplands of Baluchistan, Pakistan. *Pak. J. Bot*., 43(2): 961-969.

Agegnehu, G., A. Ghizaw and W. Sinebo. 2006. Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. *Eur. J. Agron*., 25: 202-207.

Alam, M.Z. and S.A. Haider. 2006. Growth attributes of barley (*Hordeum vulgare* L.) cultivars in relation to different doses of nitrogen fertilizer. *J. Life Earth Sci.,* 1(2): 77-82.

Anil, L., J. Park, R.H. Phipps and F.A. Miller. 1998. Temperate intercropping of cereals for forage: a review of the potential for growth and utilization with particular reference to the UK. *Grass Forage Sci*., 53: 301-317.

Anonymous. 2010-2011. Economic Survey. Govt. of Pakistan, Finance Division, Economic Advertiser Wing. Islamabad. 29 p.

Ansar, M., Z.I. Ahmad, M.A. Malik, M. Nadeem, A. Majeed and B.A. Rischkowsky. 2010. Forage yield and quality potential of winter-cereal vetch mixtures under rainfed conditions. *Emir. J. Food Agric.,* 22(1): 25-36.

Anwar, A., M. Ansar., M. Nadeem, G. Ahmad, S. Khan and A. Hussain. 2010. Performance of non-traditional winter legumes with oats for forage yield under rainfed conditions. *J. Agri. Res.,* 48(2): 171-179.

Assefa, G. and I. Ledin. 2001. Effect of variety, soil type and fertilizer on the establishment, growth, forage yield, quality and voluntary intake by cattle of oats and vetches cultivated in pure stands and mixtures. *Anim. Feed. Sci. Tech*., 92: 95-111.

Banik, P., A. Midya, B.K. Sarkar and S.S. Ghose. 2006. Wheat and chickpea intercropping systems in an additive series experiment: advantages and weed smothering. *Eur. J. Agron.*, 24: 325-332.

Beadle, C.L. 1985. Plant Growth Analysis. In: *Techniques in Bioproductivity and Photosynthesis*. (Eds.): J. Coombs, D.O. Hall, S.P. Long and J.M.O. Scurlock, 2nd ed., Pergamon Press, Oxford, N.Y. pp. 21-22.

Bedoussac, L. and E. Justes. 2010. Dynamic analysis of competition and complementarity for light and N use to understand the yield and the protein content of a durum wheat-winter pea intercrop. *Plant Soil*, 330: 37-54.

Caballero, R., E.L. Goicoechea and P.J. Hernaiz. 1995. Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of common vetch. *Field Crops Res*., 41: 135-140.

Chen, C., W.A. Payne, R.W. Smiley and M.A. Stoltz. 2003. Yield and water use efficiency of eight wheat cultivars planted on seven dates on Northern Oregon. *Agron. J.,* 95: 836-843.

Dhima, K.V., A.S. Lithourgidis, I.B. Vasilakoglou and C.A. Dordas. 2007. Competition indices of common vetch and cereal intercrops in two seeding ratio. *Field Crops Res*., 100: 249-256.

Giacomini, S.J., E.R.O. Vendruseolo, M. Cubilla, R.S. Nicoloso and M.R. Fries. 2003. Dry matter, C/N ratio and nitrogen, phosphorus and potassium accumulation in mixed soil cover crops in Southern Brazil. *Rev. Bras. Ciencia Solo*., 27: 325-334.

Jones, M.J. and Z. Arous. 1999. Effect of time of harvest of vetch (*Vicia sativa* L.) on yields of subsequent barley in a dry Mediterranean environment. *J. Agron. Crop Sci*., 182: 291-294.

Khan, A.L., Z.K. Shinwari, Yoon-Ha Kim, M. Waqas, M. Hamayun, M. Kamran and In-Jung Lee. 2012. Isolation and detection of Gibberellins and indole acetic acid from Endophyte *Chaetomium globosum* LK4 growing with drought stressed plant. *Pak. J. Bot*., 44(5): 1601-1607.

Kocer, A. and S. Albayrak. 2012. Determination of forage yield and quality of pea (pisum sativum L.) mixtures with oat and barley. *Turkish J. Field Crops*, 17(1): 96-99.

Nadeem, M., M. Ansar, A. Anwar, A. Hussain and S. Khan. 2010. Performance of winter cereal-legume fodder mixtures and their pure stands at different growth stages under rainfed conditions of Pothowar. *J. Agri. Res.,* 48(2): 181-192.

O'Connell, M.G., G.J. O'Leary, D.M. Whitfield and D.J. Connor. 2004. Interception of photosynthetically active radiation and radiation-use efficiency of wheat, field pea and mustard in a semi-arid environment. *J. Field Crops Res*., 85: 111-124.

Pala, M., J. Ryan, H. Zhang, M. Singh and H.C. Harris. 2007. Water-use efficiency of wheat-based rotation systems in a Mediterranean environment. *J. Agric. Water Management.*, 93: 136-144.

Parveen, S., I.A. Qamar, A. Ali and M. Arshad. 2001. Effect of legume-grass mixture on forage yield and quality in the Pothwar plateau of Pakistan. *J. Biol. Sci*., 1(9): 809-811.

Shah, H., M.A. Khan, T. Azeem, A. Majid and A. Mehmood. 2012. The Impact of Gypsum application on groundnut yield in rainfed Pothwar: An Economic Perspective. *The Lahore J. Econ*., 17(1): 83-100.

Shobeiri, S.S., D. Habibi, A. Kashani, F. Paknejad, H. Jafary, M.J. Al-Ahmadi, M.R. Tookalloo and J. Lamei. 2010. Evaluation of hairy vetch (*Vicia villosa* Roth) in pure and mixed cropping with barley (*Hordeum vulgare* L.) to determine the best combination of legume and cereal for forage production. *Am. J. Agric. & Biol. Sci*., 5 (2): 169-176.

Steel, R.G.D., J.H. Torrie and D.A. Dickny. 1997. Principles and procedures of statistics, a biological approach. 3rd Edition. McGraw Hill Book Co., Inc., NY, USA. pp. 352-358.

Tuna, C. and A. Orak. 2007. The role of intercropping on yield potential of common vetch (*Vicia sativa* L.) / oat (*Avena sativa* L.) cultivated in pure stand and mixtures. *J. Agric. Biol. Sci*., 2: 14-19.

Usmanikhail, M.U., S.D. Tunio, G.H. Jamro, F.C. Oad, S.W. Hassan, Q.D. Chachar, M.A. Khanzada and A.W. Gandahi. 2012. Agronomic and economic effect of intercropping sugarbeet with oilseeds and lentil. *Pak. J. Bot*., 44(6): 1983-1988.

Vasilakoglou, I.B., A.S. Lithourgidis and K.V. Dhima. 2005. Assessing common vetch–cereal intercrops for suppression of wild oat. In: Proceedings of 13th International Symposium, Session S5, European Weed Research Society, Bari, Italy.

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