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Artículo

Forage productivity of cowpea [*Vigna unguiculata* (L.) Walp] cultivars improves by optimization of spatial arrangements

La productividad del forraje de frijol [Vigna unguiculata (L.) Walp] mejora con la optimización de los arreglos espaciales

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Abstract:

Sustainable production of quality forages in sufficient quantities constitutes one of the biggest challenges for profitable dairy farming. Forage legumes including cowpea offer a feasible solution to meet this task but planting geometry for spreading and erect types of varieties needs to be optimized. Two cowpea varieties (P-518 and Rawan-2003) were sown to different row spacing (30, 45 and 60 cm), while broadcasted crops were kept for comparison. Factorial arrangement of randomized complete block design (RCBD) was employed to carry out the field trial with four replicates. Dry matter biomass, quality variables, net income and benefit-cost ratio were taken as experimental variables. Rawan-2003 (spreading type) sown at 45 cm spaced rows gave significantly (*P*≤0.01) higher dry matter biomass (8.26 and 9.03 t ha^{-1} in 2013 and 2014, respectively) along with significantly (*P*≤0.05) improved forage quality (especially higher crude protein and lower crude fiber contents). The same variety and spatial arrangement resulted in the highest net income and benefit-cost ratio (BCR) (4.66 and 4.85 in 2013 and 2014 respectively). P-518 (erect type) gave better results with closer inter-row spacing (30 cm spaced rows), while broadcasting of both cowpea varieties proved to be inferior to all other spatial arrangements.

Key words: Animal nutrition, Cowpea fodder, Dairy farming, Forage production, Legumes, Planting geometry, Profitability.

Resumen:

La producción sustentable de forrajes de calidad en cantidades suficientes constituye uno de los mayores retos para la ganadería lechera rentable. Leguminosas forrajeras incluyendo el frijol caupí ofrecen una solución factible para cumplir con esta tarea, pero se deben optimizar los arreglos de la siembra y la selección de variedades rastreras y erectas. Se sembraron dos variedades de frijol (P-518 y Rawan-2003) con diferente espaciamiento entre surcos (30, 45 y 60 cm), mientras que cultivos ya establecidos se mantuvieron para la comparación. Se utilizó un arreglo factorial de diseño de bloques completos al azar con cuatro repeticiones para llevar a cabo el ensayo de campo. Biomasa de materia seca, las variables de calidad, ingreso neto y relación beneficio-costo se tomaron como variables experimentales. Rawan-2003 (tipo rastrero) sembrado en hileras de 45 cm de espaciado dio significativamente (*P*≤0.01), mayor biomasa de materia seca (8.26 y 9,03 t ha^{-1} en 2013 y 2014, respectivamente) y mejoró significativamente (*P*≤0.05) la calidad del forraje (mayor proteína cruda y menor contenido de fibra cruda). La misma variedad y arreglo espacial resultaron en el mayor ingreso neto y relación beneficio-costo (BCR) (4.66 y 4.85 en 2013 y 2014 respectivamente). El tipo erguido P-518 dio mejores resultados con espaciamiento entre surcos más cercanos (30 cm), mientras que las variedades de frijol testigo demostraron ser inferiores a todos los otros arreglos espaciales.

Palabras clave: Alimentación animal, Frijol caupí, Calidad forraje, Leguminosas, Rentabilidad.

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Introduction

Sustainable production of quality forages in ample quantities is imperative for a profitable dairy farming[1,2]. There is a renewed interest for increasing the production of quality forages in order to earn the maximum economic returns by increasing milk and meat production[3]. Quality forages with appreciable agro-qualitative attributes can go a long way in ensuring the food security of skyrocketing population by a sustainable increase in ruminant's productivity. Cereal forages, though yield copious and substantial quantities of green forage for ruminants, but these are indigent in nutrients with low digestibility which decrease their value in qualitative terms. Costly additives and protein rich concentrates significantly enhance cost of production and ultimately decrease the net profit[4,5]. Forage legumes have become even more important in recent years owing to their superior quality than grasses and have the ability to fix atmospheric nitrogen.

Cowpea (*Vigna unguiculata* L.) also known as rawan, black-eyed pea, Chinese long bean, cream pea, clay pea, southern pea, sow-pea, asparagus bean and yard-long bean, constitutes excellent forage for dairy cows[6,7]. It is also referred as the crop of hungry season owing to its harvesting before cereals during summer. Cowpea is being grown on vast areas of Asia, Americas and Africa owing to its hardy nature to tolerate scorching heat of sun and moderate drought. It can be successfully grown on soils with low organic matter and diminished fertility status[8]. Owing to its heat-loving nature, cowpea holds the potential to provide green forage in mid-summer when other forages become vanished. But cowpea has been reported to yield significantly less green biomass in comparison with cereal forages which is not sufficient to feed dairy animals during summer[9]. However, cowpea forage is superior in quality (higher protein contents and dry matter digestibility), therefore enhances fattening of animals along with improving milk production.

There are several factors which limit and undermine green forage yield of cowpea especially the serious lack of high yielding forage genotypes along with its sowing under suboptimal spatial arrangements. Spatial arrangement determines the utilization efficacy of soil applied (water and nutrients) and environmental growth resources (sunlight and gases). Spatial arrangement also influences the degree of intra-species competition and ultimately determines the green forage yield[6]. But there is a serious lack of field investigations regarding testing of cowpea cultivars under semi-arid conditions of Faisalabad region, while previous studies report contradictory results regarding the most appropriate and complementary spatial arrangement for cowpea grown as a forage crop.

Thus, it was hypothesized that spreading and erect type of forage cowpea cultivars react differently to different closer and wider planting geometries. It was further hypothesized that forage productivity of cowpea cultivars could be increased by lowering inter-row spacing. Furthermore, in order to fill knowledge and research gap, this field trial was executed with following objectives: (i) to ascertain the highest forage yield cowpea variety with the highest quality attributes under agro-climatic conditions of Faisalabad in irrigated conditions; (ii) to find out the most suitable and appropriate spatial arrangement for erect and spreading types of cowpea cultivars; (iii) to determine the profitability and economic returns rendered by cowpea varieties under varied spatial arrangements.

Material and methods

Experimental site description

The study was carried out at different locations of Agronomic Farm of University of Agriculture Faisalabad, Pakistan during summer months of 2013 and 2014 under same agro-climatic conditions. The geographical coordinates of the experimental site are 30.35-41.47° N latitude and 72.08-73.40 °E longitude, having an elevation of 184 m. The climate of experimental site is semi-arid according to Koppen-Geiger classification, while the soil of the experimental area belongs to Haplic Yermosols of FAO soil classification scheme[7].

Experimental treatments and design

Two varieties of forage cowpea (P-518 and Rawan-2003) were sown at 30, 45 and 60 cm spaced rows and as broadcasted crops. In this way, there were a total of 8 treatments including V_1 (P-518 broadcasted), V_2 (P-518 sown in 30 cm spaced rows), V_3 (P-518 sown in 45 cm spaced rows), V_4 (P-518 sown in 60 cm spaced rows), V_5 (Rawan-2003 broadcasted), V_6 (Rawan-2003 sown in 30 cm spaced rows), V_7 (Rawan-2003 sown in 45 cm spaced rows), V_8 (Rawan-2003 sown in 60 cm spaced rows). The net plot size was 3.6 m × 15.0 m. Each experimental plot had 12, 8 and 6 lines for 30, 45 and 60 cm spaced rows, respectively. There were four replications for each treatment. Factorial arrangement of randomized complete block design (RCBD) was employed to carry out this field trial during both years.

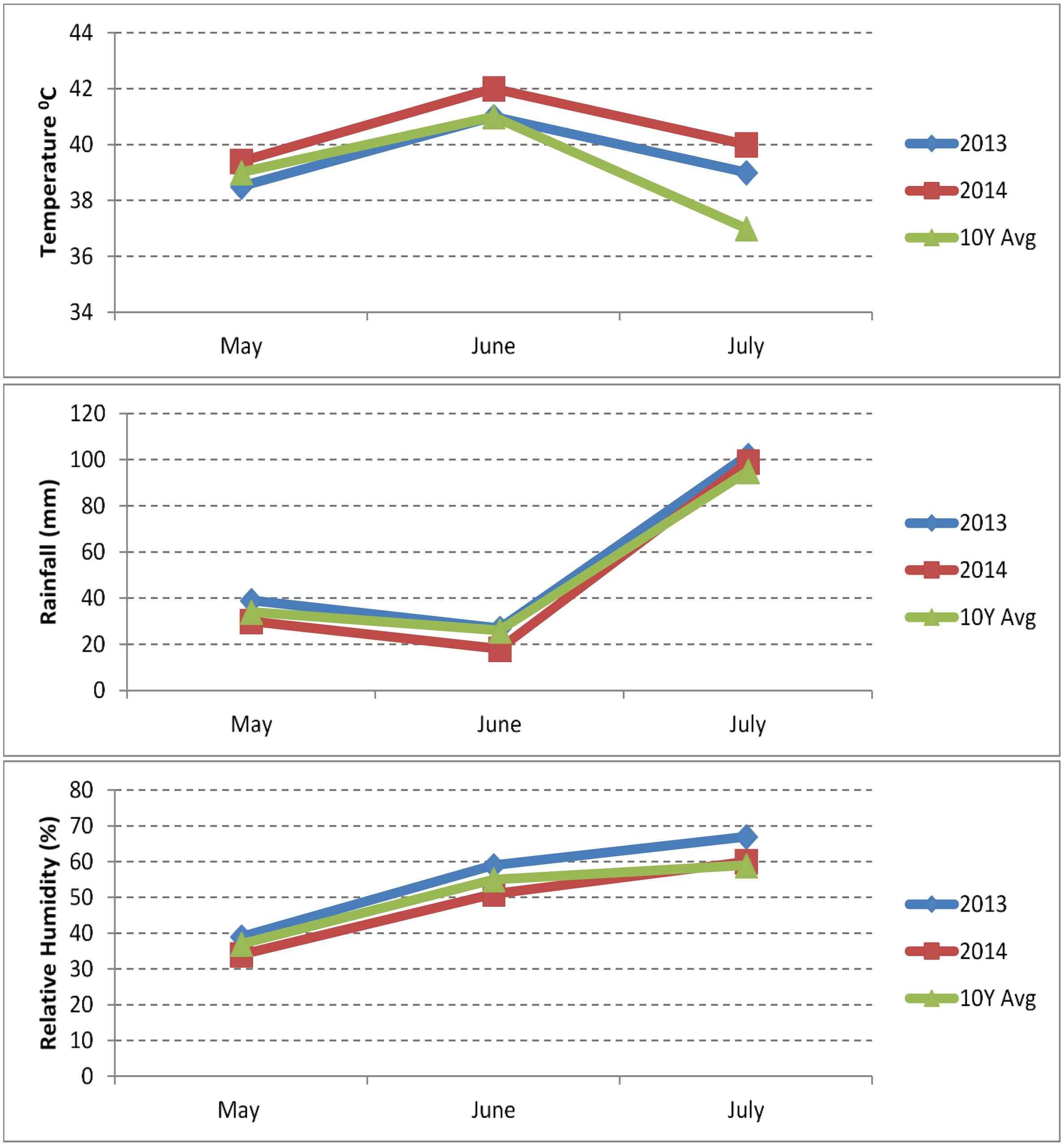
Crop husbandry

For conducting pre-sowing physico-chemical analysis of the experimental units, soil samples were collected from 15 and 30 cm depth and then thoroughly homogenized, while representative samples were taken for recording the soil quality (Table 1). Meteorological data regarding temperature, rainfall and relative humidity during crop growing seasons were also collected from meteorological observation center located close to the field trials (Figure 1).

Table 1: Pre-sowing physico-chemical analysis of experimental soil from composite samples taken at 30 cm and 60 cm depth at Faisalabad (Pakistan) during 2013 and 2014

Characteristics	**Values**	
Mechanical analysis	**2013**	**2014**
Sand, %	60	58
Silt, %	18	19.2
Clay, %	22	22.8
Textural class	Sandy clay loam	Sandy clay loam
Chemical analysis	**2013**	**2014**
pH	7.9	8.0
EC, dSm^{-1}	1.51	1.53
Organic matter, %	0.65	0.69
Total nitrogen, mg kg^{-1}	285.7	298.1
Available phosphorous, mg kg^{-1}	6.3	6.9
Available potassium, mg kg^{-1}	145	151

Figure 1: Meterlogical data for temperature (^{0}C), rainfall (mm) and relative humidity (%) during crop growing seasons at Faisalabad (Pakistan) during 2013 and 2014



The seed rate for both cv. P-518 and cv. Rawan-2003 was 35 kg ha^{-1} and sowing was done on May 16 and May 21 during 2013 and 2014, respectively, with the help of hand-pulled single row drill. N:P at the rate of 60:22 were applied as urea and single super phosphate (SSP). Phosphorous was applied in a single dose at the time of sowing while nitrogen was applied in two equal splits (half dose at the time of sowing and remaining with 1st irrigation at 15 d after sowing (DAS). Three irrigations were applied at 15, 30 and 50 DAS. Manual harvesting (single cut) at one inch from ground surface was done with sickle after 78 and 73 DAS in 2013 and 2014, respectively at pod filling stage.

Data collection

Dry matter yield was determined by harvesting ten plants from the middle rows of each replicate and were chopped with an electric fodder cutter. Their fresh weight was noted by using an electric balance and 500 g sample was taken from it. These samples were then placed in an oven at 70 ^{o}C until a constant weight was obtained, which was then used to calculate dry matter yield per hectare. Crude protein was determined using Macro-KJeldahl method involving acid (K_2SO_4, $CuSO_4$ and $FeSO_4$ in 10:0.5:1 ratio) digestion which gave nitrogen. The obtained nitrogen was multiplied with a constant factor (6.25) to calculate crude protein. In order to calculate crude fiber, digestion of dried samples with H_2SO_4 and NaOH was performed and then muffle furnance was used to burn non-fibrous substances. Then, crude fiber was calculated by following procedure as outlined by AOAC[10]:

Crude fiber (%) = Dried residues weight- ash weight × 100 ....(1)

Soxhlet extraction apparatus was used to calculate ether extractable fat, while total ash was determined using muffle furnace technique which involved burning of dried samples to ash at 600 ^{0}C (AOAC)[10].

Cost of production

Cost of production for both years was calculated in order to perform economic analysis. The cost of production was computed by calculating fixed expenditures including costs of land preparation, sowing, irrigations, fertilizers, harvesting, transportation and land rent. Then the variable expenditures per treatment were also calculated. Total expenditures for each treatment were calculated by the following:

Total cost = Fixed cost + Variable cost ....(2)

Gross income was calculated as:

Gross income = Forage yield (t ha^{-1}) × Market rate (US\$ t^{-1}) ....(3)

Net income rendered by different treatments was calculated by deducting the total expenditure from the gross income[11].

Net income = Gross income – Total cost ....(4)

Benefit-cost ratio (BCR) was determined by using the following formula:

BCR = Gross income/ Total cost ....(5)

Statistical analysis

For performing statistical analysis, the collected data were subjected to computer run statistical program "MSTAT-C"[12,13] by employing analysis of variance (ANOVA) technique. The grouping of the means was done for orthogonal contrasts; (i) variety *versus* spatial arrangements, (ii) variety *versus* year, (iii) spatial arrangements versus year and (iv) variety × spatial arrangements × year. The level of significance was defined by P<0.05 until and unless stated otherwise.

Results and discussion

Dry matter biomass

The individual effect of varieties and spatial arrangements was found to be significant (Table 2), while the interaction effects of cultivar × spatial arrangements as well as cultivar × spatial arrangements × year were also significant, while interaction effects of cultivar × year and spatial arrangement × year were non-significant.

Table 2: Dry matter yield of cowpea varieties sown under different spatial arrangements at Faisalabad (Pakistan) during 2013 and 2014

Treatments	**Dry matter yield (t ha^{-1})**	
	2013	**2014**
V_1 (P-518 broadcasted)	6.27±0.09f	6.39±0.24f
V_2 (P-518 sown in 30 spaced rows)	7.09±0.17c	7.22±0.47c
V_3 (P-518 sown in 45 cm spaced rows)	6.83±0.49d	6.95±0.29de
V_4 (P-518 sown in 60 cm spaced rows)	6.55±0.67ef	6.71±0.16e
V_5 (Rawan-2003 broadcasted)	6.61±0.08e	6.98±0.27d
V_6 (Rawan-2003 sown in 30 cm spaced rows)	7.39±0.51b	7.62±0.34b
V_7 (Rawan-2003 sown in 45 cm spaced rows)	8.26±0.12a	9.03±0.36a
V_8 (Rawan-2003 sown in 60 cm spaced rows)	6.78±0.38de	7.13±0.019cd
Cultivars × Spatial arrangement	*	**
Cultivars × Spatial arrangement × Year	*	*
Cultivars × Year	NS	NS
Spatial arrangement × Year	NS	NS

Mean values followed by standard deviation having different letters are different (P<0.05). **= P<0.01; *= P<0.05; NS= Non-significant.

Statistical analysis revealed that both varieties of cowpea differed significantly ($P \leq 0.01$) in their potential for dry matter biomass production (Table 2). It was also observed that spatial arrangements were effective ($P \leq 0.05$) in influencing the productivity of forage cowpea in terms of dry matter biomass. It was found that Rawan-2003 was more productive than P-518 ($P \leq 0.05$) especially when it was sown at 45 cm spaced rows (V_7) (8.26 and 9.03 t ha^{-1} in 2013 and 2014, respectively). The same cowpea variety sown in 30 cm spaced rows (V_6) followed it, while the lowest dry matter yield (6.27 and 6.39 t ha^{-1} in 2013 and 2014, respectively) was recorded by P-518 which was broadcasted (V_6). Overall, Rawan-2003 performed better at 45 cm spaced rows, while P-518 had better results at 30 cm spaced rows.

One of the apparent reasons for this performance might be the spreading nature of Rawan-2003 which required more space to grow in comparison with P-518. Another reason could be higher genetic potential of Rawan-2003 than P-518 as far as dry matter biomass production was concerned. Similar findings were reported by other researchers(14), who suggested that very few varieties of cowpea have good genetic potential to yield reasonably higher quantities of green forage owing to higher photosynthesis rate and producing more number of leaves and branches along with utilizing plant nutrients more efficiently. Furthermore, it was recorded that an appropriate agronomic management including an optimum spatial arrangement was vital to achieve higher forage yield as well as genetic potential of the variety. It was also observed that cowpea performed better when inter-row spacing was maintained at 45 cm in comparison with 60 and 75 cm spaced rows. Cowpea forage yield was increased with decreasing row spacing, thus narrow row spacing could bring positive results for erect type varieties of cowpea(15). Contrarily, another study(16)reported that cowpea intercropped with pearl millet performed better in 30 cm spaced rows in comparison with wider row spacing.

Quality of forage

The productivity and performance of dairy cows is directly influenced by quality attributes of feedstuffs, especially higher crude protein has been reported to be effective in increasing milk production. Similarly, fiber is considered to be an anti-nutritional factor in forages and its low concentration reduced the bulkiness of feed which caused a significant increase in feed intake(15).

Rawan-2003 cultivar was significantly ($P \leq 0.05$) superior in term of crude protein contents (18.93 and 18.97 % in 2013 and 2014, respectively) and the lowest crude fiber (25.64 and 25.63 % in 2013 and 2014, respectively) especially when it was sown in 45 cm spaced rows (V_7). Protein of Rawan-2003 cultivar decreased with increase in inter-row spacing. P-518 recorded comparatively lower crude protein and significantly ($P \leq 0.05$) higher crude fiber contents than Rawan-2003, especially when it was broadcasted (V_7) (Table 3). These results corroborate with the conclusions made by another field research(17), where it was reported that crude protein and crude fiber contents of forage cowpea varieties could be due to genetic potential, however closer line sowing (30 cm) was also found to be effective in increasing crude protein and reducing fiber contents of cowpea forage. Furthermore, spreading type of cultivars recorded higher protein while erect verities of cowpea yielded more fiber contents.

Table 3: Agro-qualitative attributes of cowpea varieties sown under different spatial arrangements at Faisalabad (Pakistan) during 2013 and 2014

Treatments	Crude protein (%)		Crude fiber (%)		Ether extractable fat (%)		Total ash (%)	
	2013	2014	2013	2014	2013	2014	2013	2014
V_1 (P-518 broadcasted)	17.23±0.11d	17.49±0.28e	27.33±0.09b	27.18±0.41b	1.63±0.67e	1.57±0.05d	11.34±0.33f	11.29±0.05g
V_2 (P-518 sown in 30 spaced rows)	17.38±0.33cd	17.57±0.09d	27.24±0.23c	27.15±0.18bc	1.71±0.54d	1.73±1.14c	11.51±0.08e	11.47±1.19f
V_3 (P-518 sown in 45 cm spaced rows)	17.31±0.12d	17.61±0.18cd	27.29±0.34bc	27.10±1.05c	1.74±0.19d	1.76±0.45c	11.56±0.51d	11.51±0.08e
V_4 (P-518 sown in 60 cm spaced rows)	17.43±0.47c	17.47±0.75e	27.59±0.17a	27.51±0.22a	1.65±0.35e	1.59±0.29d	11.31±0.34f	11.26±0.71g
V_5 (Rawan-2003 broadcasted)	18.71±0.07b	18.64±0.20c	25.93±0.08e	25.87±0.39e	1.84±0.79bc	1.87±0.37b	11.71±0.17c	11.69±0.37c
V_6 (Rawan-2003 sown in 30 cm spaced rows)	18.89±0.25a	18.85±0.16b	25.61±0.38f	25.50±0.73g	1.89±0.28b	1.91±0.11ab	11.84±0.09b	11.80±0.78b
V_7 (Rawan-2003 sown in 45 cm spaced rows)	18.93±0.29a	18.97±0.49a	25.64±0.48f	25.63±0.15f	1.91±0.66a	1.94±1.05a	11.90±0.71a	11.92±0.42a
V_8 (Rawan-2003 sown in 60 cm spaced rows)	18.67±0.31b	18.69±0.14c	26.19±0.22d	26.36±0.50d	1.80±0.09c	1.87±0.42b	11.69±0.83c	11.60±0.09d
Cultivars × Spatial arrangement	*	*	*	*	*	*	*	*
Cultivars × Spatial arrangement × Year	*	*	*	*	*	*	*	*
Cultivars × Year	NS	NS	NS	NS	NS	NS	NS	NS
Spatial arrangement × Year	NS	NS	NS	NS	NS	NS	NS	NS

Mean values followed by standard deviation having different letters are different (P<0.05).

** = P<0.01; * = P<0.05; NS= Non-significant.

Fats and ash are also important quality parameters of animal feed owing to their vital role in a variety of metabolic processes. Rawan-2003 recorded significantly (P≤0.05) higher ether extractable fat (1.91 and 1.9 4% in 2013 and 2014, respectively) and total ash (11.90 and 11.92 % in 2013 and 2014, respectively) contents particularly it remained unmatched when it was sown in 45 spaced rows (V_7). On the other hand, P-518 sown as broadcasted crop (V_1) recorded the lowest ether extractable fat and total ash contents. These results are in complete confirmation with those of another study[18], which reported that spatial arrangement was found to be an important factor in influencing fat and ash contents. However, these finding contradict with the conclusions reported by another field investigation[19], which suggested that spatial arrangements did not affect fat and ash contents of cowpea.

Economic analysis

Profit has occupied central place in recent commercial and profit-oriented farming as reduction in economic returns result in shifting to other crops. Rawan-2003 sown in 45 cm spaced rows gave the highest net income (US$. 869.50 and 923.50 in 2013 and 2014, respectively) (V_7) and it was followed by same cowpea variety sown at 30 cm spaced rows (V_6) (Tables 4 and 5). The lowest net income was generated by P-518 when it was broadcasted (V_1). However, P-518 recorded the highest net income when it was sown at 30 cm spaced rows. Broadcast method of sowing resulted in the lowest net income for both varieties of forage cowpea.

Table 4: Economic analysis for cowpea varieties sown under different spatial arrangements at Faisalabad (Pakistan) during 2013

Treatments	Total expenditures (US$ ha^{-1})	Gross income (US$ ha^{-1})	Net income (US$ ha^{-1})	Benefit-cost ratio
V_1 (P-518 broadcasted)	240.00	792.00	552.00	3.30
V_2 (P-518 sown in 30 spaced rows)	236.50	915.00	678.50	3.86
V_3 (P-518 sown in 45 cm spaced rows)	234.75	870.00	635.25	3.70
V_4 (P-518 sown in 60 cm spaced rows)	233.00	83.700	604.00	3.59
V_5 (Rawan-2003 broadcasted)	243.50	840.00	596.50	3.44
V_6 (Rawan-2003 sown in 30 cm spaced rows)	239.50	945.00	705.50	3.94
V_7 (Rawan-2003 sown in 45 cm spaced rows)	237.50	1107.00	869.50	4.66
V_8 (Rawan-2003 sown in 60 cm spaced rows)	235.50	843.00	607.50	3.57

Table 5: Economic analysis for cowpea varieties sown under different spatial arrangements at Faisalabad (Pakistan) during 2014

Treatments	Total expenditures (US$ ha^{-1})	Gross income (US$ ha^{-1})	Net income (US$ ha^{-1})	Benefit-cost ratio
V_1 (P-518 broadcasted)	240.00	837.00	597.00	3.48
V_2 (P-518 sown in 30 spaced rows)	236.50	948.00	711.50	4.00
V_3 (P-518 sown in 45 cm spaced rows)	234.75	882.00	647.25	3.75
V_4 (P-518 sown in 60 cm spaced rows)	233.00	861.00	628.00	3.69
V_5 (Rawan-2003 broadcasted)	243.50	894.00	650.50	3.67
V_6 (Rawan-2003 sown in 30 cm spaced rows)	239.50	1035.00	795.50	4.32
V_7 (Rawan-2003 sown in 45 cm spaced rows)	237.50	1161.00	923.50	4.85
V_8 (Rawan-2003 sown in 60 cm spaced rows)	235.50	906.00	670.50	3.84

Following the trend, Rawan-2003 sown at 45 cm spaced rows (V_7) remained unmatched in terms of benefit-cost ratio (BCR) (4.66 and 4.85 in 2013 and 2014, respectively) and it was followed by same cowpea variety sown at 30 cm spaced rows with BCR of 3.94 and 4.32 in 2013 and 2014, respectively, while wider row spacing did not work at par with those of 30 and 45 cm spaced rows. Both varieties sown with broadcast method resulted in significantly lower BCR particularly P-518 witnessed the lowest BCR and this trend was evident during both years. The results of this study corroborate the findings of other investigations(20,21), where comparatively closer spatial arrangement for different cowpea cultivars was instrumental in generating the highest net income owing to higher production per unit of land basis, while wider intra-row spacing caused a considerable reduction in economic yield which was bound to bring down the net income. Similarly in complete agreement of this research's findings, a number of researches(22,23,24) also reported that closer row spacing of different legumes including cowpea were effective in increasing net income as well as benefit-cost ratio. They concluded that by optimizing spatial arrangements, there was no additional cost involved but it significantly increased forage yield of soybean which increased net income as well as benefit-cost ratio.

Conclusions and implications

Cowpea variety Rawan-2003 had higher dry matter yield, crude protein, ether extractable fat and ash contents and lower crude fiber especially when it was sown at 45 cm spaced rows. The same cowpea variety and spatial arrangement produced the highest net income and benefit-cost ratio. Erected cowpea varieties sown at reduced rows spacing like 30 cm could be more productive than wider row spacing and opposite could be true for spreading type of cowpea varieties for obtaining lush green forage with good quality traits in order to boost the milk production of large ruminants.

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