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ARTICLE

Effects of Rate and Source Organo-Mineral Material on Forage Yield and Nutritive Value of Barley-Pea Mixed under Arid Conditions

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ABSTRACT

Cereal-legume intercropping plays a vital role in the subsistence food production system that prevails in the arid regions. It not only provides profitable crop productivity for agricultural communities but also plays an important role in improving soil fertility. Therefore, the present research was conducted to assess the effect of the organic and mineral fertilizers on the forage yield and nutritional value in barley-pea intercropping system. The results revealed that the quality of forage grass is significantly influenced by both organic and inorganic fertilizer. Thus, organic fertilizer application has significantly influenced the dry matter (DM), crude ash (CA), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF). Among the treatments, organic fertilizer added at rate of 35 m^{-3} ha^{-1} produced the maximum fresh and dry matter in barley and peas. In addition, the same level of organic fertilizer also improved silage composition by significantly increasing the protein and fiber content and showed highest the values. Based on overall results, it is concluded that organic fertilizer treatment (35 m^{-3} ha^{-1}) has the potential as an effective strategy to improve the productivity and nutritional quality of the barley-pea intercropping system in arid areas. The results revealed that organic fertilizer can be utilized in sustainable agricultural as a source of nutrients for numerous various crops under arid conditions.

KEYWORDS

Organic fertilizer; barley; pea; yield; quality; hay; silage

1 Introduction

By the year 2050, it is a great challenge in agriculture to ensure food security for the burgeoning world population by mitigating adverse environmental conditions. Therefore, it is necessary to adopt sustainable production practices for increasing agricultural productivity in response to changing climate, resources rarefaction, and losses of fertile lands. For sustainable agro ecological development, crop diversity and cropping systems must be taken into consideration. It has been recognized that intercropping systems play an important role to enhance crop yield and quality by exploiting land, light, water, and soil nutrients efficiently [1]. Growing at least two crop species in close proximity simultaneously, leading to enhanced interspecific interactions and crop diversity, is known as intercropping [2]. However, the overall yield of intercropping is higher over monocropping systems [3]. It can be explained by two major ecological principles leading to improved resource use: niche complementarity and interspecific facilitation in intercropping systems. Reduced competition due to complementary use of resources and niche differentiation within intercropped species in time, space, or forms of a given resource are the hypothesis of niche complementarity action [3]. Moreover, an intercropping system strategy can improve the sustainability of agricultural systems [4]. Intercropping systems improve yield on a given land area by making more efficient utilization of the available growth resources [4], and enhance biological activities of beneficial micro/macro-organisms in the soil as well as and suppress weeds, pests and disease incidence in crop fields [5]. The use of inorganic fertilizers alone is not so helpful, especially in intensive agricultural systems due to degradation of soil along with causing environmental pollution [6,7]. Soil degradation focuses on the reduction of organic matter as a prime issue resulting in an increase of soil acidity, an imbalance of plant nutrients, and a reduction in crop yields. It has been well established that the response of crops to applied fertilizer markedly depends on soil organic matter [8,9]. Intensive and uncontrolled use of chemical fertilizers causes pollution of the surface and groundwater. Recently, in many countries, the use of organic fertilizers is preferred over the excessive use of chemical fertilizers, which result in the increased demand of organic fertilizers [10]. Further, improvement of environmental conditions and public health, and the need to reduce costs of fertilizing crops are also important reasons for advocating the increased use of organic materials (OMs) [11]. However, the benefits derivable from the use of OMs have not been fully utilized in the arid tropics [12]. Diversification of agricultural ecosystems and effective management are the prime issues for sustainable agriculture.

Intercropping is a system that assists in developing sustainable agriculture by reducing pests, diseases, and weeds incidence as well as maintaining ecological balance, curtailing the pesticides application, exploiting resources which ultimately results in enhancing the quantity and quality of crops [13]. Interaction of mixed crops comprising one legume could be a more suitable way to obtain high yield stability and fixation of atmospheric nitrogen inputs over sole legume crops [14]. Cereal-legume intercropping could enhance multiple resource use efficiency in agroecosystems, and improve yield stability and per unit production. Annual legumes are less productive, mostly in the areas with low rainfall because they normally lie on the soil surface [15]. On the other side, the small grain cereals present high dry matter yields, even though they achieve forage with low protein [16]. Legumes are rich in protein content, whereas cereals have superior carbohydrate contents and advantages for cereals from the nitrogen fixed by legumes when they are grown in mixtures. Several investigations reported that annual legume-cereal mixtures resulted in higher production and better nutritional value than cereals grown alone [16,17]. Competition of plants for the resources in both mono- and multi-cropping systems causes a reduction in forage and grain yields while in the mixed-cropping systems compared with mono-crops of each crop species. Seeding ratios of the component crops also affect the rate of competition in the mixture [18].

The production yield of barley (*Hordeum vulgare)* forage has been equal or greater to forage production of oat *(Avena sativa* L.) in sub humid regions, whether grown alone or with pea as a companion crop for alfalfa establishment [19,20]. The advantages of intercropping cereals and legumes, in terms of forage and grain (including quality) production and economic returns, depend highly on growing conditions. With the potential of intercropping of barley and pea for productivity of forage and differentiating the forage production structure [20], and the continuous needs for quality forage, information on this system lacks under the arid conditions of the study region. Furthermore, currently, there is limited data on the forage yield and nutritive value of mixed barley-pea hay and silage yield in an intercropping system under arid conditions. So, it is essential to evaluate the combination for fertilization on a range of forage crops to verify that they can be implemented in a large variety of environments. Thus, this study was planned to evaluate the yield and quality traits of forage and silage through applications of differing organic fertilization rates in addition to regular mineral fertilization, as well as to compare, the nutritional value between hay and silage to reach better quality of healthy fodder.

2 Materials and Methods

2.1 Location and Experimental Design

The experiment was carried out in a field that had not been cultivated for the two previous years (heathland) at the Agricultural Research and Experiment Station in Dirab in the College of Food and Agricultural Sciences, King Saud University (KSU), Riyadh, Saudi Arabia, (24°25′34.43″ N, 46°39′ 10.86″ E, 571) during the years 2014 and 2015. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The plants were randomly cultivated in blocks of 6 × 2 m. Climate data for the study years are shown in Fig. 1.

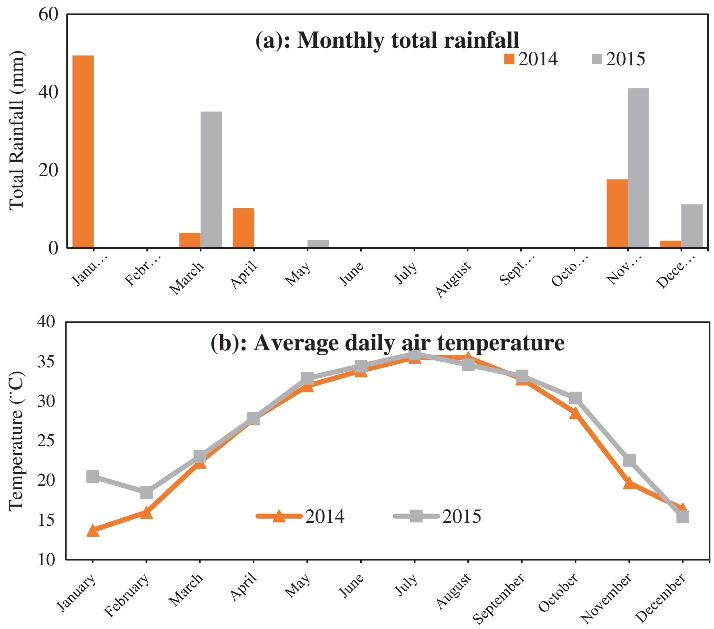

Figure 1: Temporal variations in air temperature and rainfall (a) Monthly rainfall & (b) Average air temperature during the study period

2.2 Soil Analysis

Before starting the experiment, soil samples were collected at four different depths (0–70 cm soil depth). The physical and chemical characteristics of the soil were analyzed. Analyses were performed in the laboratories of KSU and MEWA (Ministry of environment water and agriculture) in Saudi Arabia using an Inductively Coupled Plasma-Mass Spectrometer (NexION 300D, Perkin Elmer, USA). The studied soil physical and chemical characteristics pH, EC, soil texture, content of P and K are presented in Table 1.

2.3 Experimental Treatments and Design

In this study, five fertilizer treatments (organic and chemical fertilizers) were used, as showed in Table 2. Heat treated fermented cow manure free from weed seeds was used as organic fertilizer, and its composition is shown in Table 3. Three levels of organic fertilizer (15, 25 and 35 m^3/ha) along with chemical fertilizer (CF) treatment (120 kg/ha DAP) were used against non-fertilized control. Fertilizing with urea (46% N) fertilizer twice: the first application was made two weeks after the emergence of seedlings and the second was at the beginning of spiking, with 50 kg/ha each time.

Table 1: Chemical and physical properties of soils in the experimental field

Parameters	Value
pH	7.89
EC* (dS m^{-1})	0.33
Sand (%)	63
Silt (%)	26
Clay (%)	11
Soil texture	Sandy loam
P (%)	6.14
K (%)	9.81

Note: * EC: Electrical conductivity.

Table 2: Description of treatments under investigation

Treatments	Description	Application date
0 (contrl)	-	-
15 m^3/ha	Organic fermented cow manure	Before seeds sowing
25 m^3/ha		Before seeds sowing
35 m^3/ha		Before seeds sowing
Chemical Fertilizer (CF		
120 kg/ha DAP	Diammonium phosphate (DAP; 18% N, 46% P_2O_5)	Before seeds sowing
100 kg/ha urea (in two batches)	(46% N)	Twice application: two weeks after the emergence of seedlings, and at the beginning of spiking

Table 3: Components of organic manure

Components*	Value
Moisture	3.88%–11.46%
Organic matter	40%–50%
Total nitrogen (N)	1.04%–2.5%
Magnesium (Mg)	0.58%–0.68%
Calcium (Ca)	4.77%–4.92%
Sodium (Na)	0.47%–0.60%
Potassium (K)	1.27%–1.52%
Phosphorus (P)	0.42%–0.65%
Manganese (Mn)	114–155 mg/kg
Copper (Cu)	20.37 mg/kg
Iron (Fe)	0.28%–0.35%

(Continued)

Table 3 (continued)

Components*	Value
Zinc (Zn)	52–119 mg/kg
C/N Ratio	18–26
Total chloride (Cl)	1.35%–2.45%
EC	14.44–15.1 ms/cm
pH	8.24–8.35
Bulk density	0.514–0.62 kg/l
Physical test	0.25–0.63
Nematode	Negative

Note: *Source: Al-Reef Organic Fertilizers Factory Co. Riyadh 11411, Saudi Arabia.

2.4 Plant Cultivation and Sampling, Processing, Yield, and Quality Determination

Seeds of barley (*Hordeum vulgare* cv. Gusto) and local variety field pea (*Pisum sativum var.* macrocarpon) were sown on the 9th of Dec, 2014 in lines with a spacing of 25 cm, with a mixing ratio (1:1). The sowing rate was 200 and 160 kg/ha for barley and peas, respectively. The experiment was laid out in the regular arrangement of the randomized complete block design (RCBD) with three replications. The net unit plot size was 3×2 m. The experimental plots were irrigated generally once weekly until reaching field capacity (according to soil moisture and rainfall) by surface irrigation method. Weeds were removed manually when they emerged. Plant sampling was performed at the beginning of flowering in the barley and in the middle of the flowering stage of the pea. The whole plot was harvested for each treatment to estimate the yield (t/ha).

2.5 Preparation of Hay and Silage

For hay production, a fresh sample of plants was randomly selected from treatment plot, weighed, and then dried at 65°C until the weight is constant to calculate the percentage (%) of dry matter. The dried sample was grounded finely (1 mm) and all nutritional value components were estimated.

In case of silage preparation under laboratory conditions, a random green fresh sample (at the beginning of the barley milky white period, and the beginning of the formation of pea pods) was taken, cut into small pieces, and left in the field for about four hours to dry, after which it was gently press into a sealed glass jar. The jar was kept in the dark at room temperature (approximately 25°C). After eight weeks, a sample of the silage was taken, dried at 65°C, and then the percentage of dry matter was estimated.

2.6 Forage Quality Analysis

The nutritive value of the forage samples from hay and silage were estimated in the laboratories of Verb and Deutscher Landwirtschaftlicher Untersuchungsund Forschungsanstalten (VDLUFA) e. V., Speyer, Germany. Near-infrared spectroscopy (NIRS) was used to determine percentages of crude ash (CA) content, crude protein (CP), crude fiber (CF), crude fat (CFA), water-soluble carbohydrates (WSC), neutral detergent fiber (NDF), acid detergent fiber (ADF) and digestibility (DIG) in each forage sample.

The components of all feed mixtures, treatments and replicates were evaluated by the (NIRS) after performing the necessary calibration according to the species of plant sample using HPLC device.

The measurements were carried out with the NIRS instrument (Technicon 500, Technicon Industrial Systems, NY, USA). With a spectrum from 1100 to 2498 nm, the samples were measured in 2 nm steps and 32-fold repetitions. The calculation was done using the program WinISI II, version 1.50. The calibration set was based on the reference analysis of the wet chemical laboratory tests of the VDLUFA. H test using in the ISI routine, separate samples (15% of the total sample size) were filtered from the spectra and referenced using a wet chemical method.

2.7 Data Analysis

The analysis of variance (ANOVA) was used to determine treatments means significance and the least significant difference (LSD) method was put into use at a significance level of $P \leq 0.05$. All statistical tests were performed using SPSS statistics 20.0 software (IBM, Armonk, NY, USA).

3 Results and Discussion

3.1 Hay

The forage quality of barley/pea mixed hay gradually improved with the increase in the amount of organic fertilizer, while the chemical fertilizer treatment remained the best values of fresh weight (FW) and dry matter (DM), but it was not as good as organic fertilizer afterward. The application of different levels of organic fertilizer showed statistically significant changes in the protein content. The increase of organic fertilizer rate, the CP gradually increased, compared with the other treatments; the increase rate was higher, with the treatment of 35 m^3/ha (Tables 4, 5). The highest CP and CA were recorded in experimental units receiving 35 kg/m^3/ha organic fertilizer, while the lowest values of those were recorded in the control treatment (Table 4). Nevertheless, different levels of organic manures had very significant effects on the CF, CFA, WSC, NDF, and ADF of the mixture (Table 4). The highest value was obtained in the control condition. The maximum digestibility was recorded by 35 m^3/ha organic fertilizer application (Table 4). The application of vermicompost and compost significantly increased the biological function of soybean due to high enzymatic activity [21]. In our study, intercropping of legumes with cereal crops increased the CP content of hay. Our results also agree with the findings of [13], who reported that intercropping with maize increased the yield and protein content. The intercropping of legumes and cereals can improve the crude protein content due to enhanced production and maize protein content [14]. Legumes are rich in protein, while cereals have higher carbohydrate contents, and the benefits cereals from the nitrogen fixed by legumes once they are grown in mixtures [16].

Table 4: Effects of organic and mineral fertilizers on productivity and forage quality of hay of barley/pea mixture

Treatments	FM (t/ha)	DM (%)	DM (t/ha)	CA (%)	CP (%)	CF (%)
0	25.63e	25.76a	6.61d	8.00d	12.51e	29.74a
C.F.	38.90a	23.61c	9.19a	9.35b	14.34c	29.04b
25 m^3/ha	30.03c	24.00c	7.20c	9.39b	14.78b	26.73d
15 m^3/ha	27.43d	24.73b	6.78d	8.75c	13.26d	28.00c
35 m^3/ha	33.80b	23.70c	8.01b	10.25a	15.17a	26.12e
Pr > F	0.000	0.000	0.000	0.000	0.000	0.000
Significant	*	*	*	*	*	*

Note: (C.F.): 120 kg/ha DAP + 100 kg/ha urea (in two batches); FM: fresh matter, DM: dry matter, CA: crude ash, CP: crude protein, CF: crude fibers, CFA: crude fat. Means followed by different letters are statistically different from each other according to Duncan's Multiple Range test at $P \leq 0.05$, *: significant at $P \leq 0.05$.

Table 5: Effects of organic and mineral fertilizers on productivity and forage quality of hay of barley/pea mixture

Treatments	CFA (%)	WSC (%)	NDF (%)	ADF (%)	DIG (%)
0	2.48a	10.49a	61.88a	34.25a	61.30d
(C.F.)	2.23b	6.75e	60.73b	33.19c	62.97b
25 m^3/ha	2.08c	9.17c	60.01d	33.25c	63.06b
15 m^3/ha	2.17bc	9.97b	60.36c	33.93b	61.96c
35 m^3/ha	1.92d	8.36d	58.90e	32.53d	64.13a
Pr > F	0.000	0.000	0.000	0.000	0.000
Significant	*	*	*	*	*

Note: (C.F.): 120 kg/ha DAP + 100 kg/ha urea (in two batches); WSC: water-soluble carbohydrates, NDF: neutral detergent fiber, ADF: acid detergent fiber, DIG: digestibility. Means followed by different letters are statistically different from each other according to Duncan's Multiple Range test at $P \leq 0.05$, *: significant at $P \leq 0.05$.

It has been reported that application of vermicompost significantly increased the biological fixation in soybean due to higher enzymatic activities [21]. In our study, organic manuring increased the CP in the hay of intercropped barley and pea. It was recorded that organic manuring increased the yield and quality (protein content) of maize [13]. The vermicompost application improved the forage DM, forage protein percent, and plant height in maize. However, mung bean and maize intercropping enhanced the CP content in maize and reduced the DM yield in maize [14].

3.2 Silage

Mineral and organic fertilizers showed statistically significant differences in major properties of the mixture (Tables 6, 7). Different levels of fertilizers had significant effects on the silage quality (Tables 6, 7). The highest DM (33.117%) was obtained by control treatment. In addition, the highest yield of CP (16.103%) belonged to the application of organic manure @35 m^3/ha. However, the increased level of nitrogen is the main reason for increasing the protein content in the forage, and most probably, transfer of nitrogen from legume to the grass in the intercropping system is done by direct leakage, molting nodes, root rot, ecological leaf washing, and leaf decomposition [13].

Table 6: Effects of organic- and normal fertilizer on forage quality of silage of barley/pea mixture

Treatments	DM (%)	CA (%)	CP (%)	CF (%)
0	33.12a	9.17e	12.85e	29.26a
(C.F.)	30.17b	11.76a	15.92b	26.84c
25 m^3/ha	30.90b	10.06d	14.04d	27.91b
15 m^3/ha	29.03c	10.88c	15.07c	26.61c
35 m^3/ha	28.46c	11.61b	16.10a	25.91d
Pr > F	0.000	0.000	0.000	0.000
Significant	*	*	*	*

Note: (C.F.): 120 kg/ha DAP + 100 kg/ha urea (in two batches); DM: dry matter, CA: crude ash, CP: crude protein, CF: crude fibers, CFA: crude fat. Means followed by different letters are statistically different from each other according to Duncan's Multiple Range test at $P \leq 0.05$, *: significant at $P \leq 0.05$.

Table 7: Effects of organic- and normal fertilizer on forage quality of silage of barley/pea mixture

Treatments	CFA (%)	WSC (%)	NDF (%)	ADF (%)	DIG (%)
0	3.88a	11.20a	54.99b	33.59a	64.38d
(C.F.)	3.66b	5.75e	56.52a	32.21d	66.48b
25 m^3/ha	3.65b	10.82b	54.39c	33.18b	65.36c
15 m^3/ha	3.49c	10.21c	53.40d	32.55c	66.48b
35 m^3/ha	3.33d	9.81d	52.87e	32.09d	67.06a
Pr > F	0.000	0.000	0.000	0.000	0.000
Significant	*	*	*	*	*

Note: (C.F.): 120 kg/ha DAP + 100 kg/ha urea (in two batches); WSC: water-soluble carbohydrates, NDF: neutral detergent fiber, ADF: acid detergent fiber, DIG: digestibility. Means followed by different letters are statistically different from each other according to Duncan's Multiple Range test at $P \leq 0.05$, *: significant at $P \leq 0.05$.

The maximum values (percentages) of CF, CFA, WSC, and ADF were recorded under control conditions. The highest protein percentage of forage (16.10%) was recorded with 35 m^3/ha of organic fertilizer, and the lowest (12.85%) was obtained in control. Forage yield and shoot dry weight of maize is increased significantly due to the addition of compost [22]. The application of manure improved the number of seeds per pod, seed weight, grain yield and biological yield of bean, as well as increased the crude protein content, and manure application improved harvest index, number of pods per plant, grain weight and shoots, and seeds CP concentration in bitter vetch [14]. On the other hand, application of minerals leads to increase the biomass production and the quality of the silage [23].

3.3 Hay vs. Silage

The results on the effects of organic and mineral fertilizers showed that there was a statistically significant difference between the silage and hay mixed feed (Tables 8, 9). However, the maximum DM, ash, AR, CFA, WSC, DIG appeared in the experimental unit that received organic fertilizer at a rate of 35 kg/m^3/ha. In the interaction, the highest protein content, DM, CA, CFA, and digestibility of quality traits were related to silage. The highest CF, ADF, and NDF of hay were related to hay. A number of studies have shown that earthworm compost is a stable and successful combination of soil pH, which can improve the availability of soil nutrients [24,25]. In investigation of forage barley intercropping with legumes, Strydhorst et al. [26] revealed that intercropping with legumes crops produced higher protein than barley monoculture.

Table 8: Interactive effect of hay × silage on the forage quality and yield of barley/pea mixture

	DM (%)	CA (%)	CP (%)	CF (%)
Silage	30.34a	10.70a	14.80a	27.31b
Hey	24.36b	9.15b	14.01b	27.93a
Pr > F	0.000	0.000	0.000	0.000
Significant	*	*	*	*

Note: DM: dry matter, CA: crude ash, CP: crude protein, CF: crude fibers. Means followed by different letters are statistically different from each other according to Duncan's Multiple Range test at $P \leq 0.05$, *: significant at $P \leq 0.05$.

Table 9: Interactive effect of hay × silage on the forage quality and yield of barley/pea mixture

	CFA (%)	WSC (%)	NDF (%)	ADF (%)	DIG (%)
Silage	3.59a	9.56a	54.43b	32.72b	65.95a
Hey	2.18b	8.95b	60.38a	33.43a	62.68b
Pr > F	0.000	0.000	0.000	0.000	0.000
Significant	*	*	*	*	*

Note: CFA: crude fat, WSC: water-soluble carbohydrates, NDF: neutral detergent fiber, ADF: acid detergent fiber, DIG: digestibility. Means followed by different letters are statistically different from each other according to Duncan's Multiple Range test at $p \leq 0.05$, *: significant at $p \leq 0.05$.

The previous literature recommended that with the increase in the nutritional components in soil, the nutrition of crops is also increased but up to a certain rate [27,28]. Wheat and beans intercropping showed the highest photosynthetically active radiation (PAR) efficiency over their monoculture [29]. Intercropping of maize and mung bean harvested light more efficiently, and increased the DM production [13]. Manure application improved the physical, chemical, physical and biological characteristics of soil, and increased the productivity and quality of crops [30]. A significant difference in crop yield with the application of different fertilizer sources was reported by [31,32]. The management of combined nutrients, traditional and advanced methods of nutrient handling assists to develop the ecologically sound and improved soil health and environmental sustainability [33,34]. Kennelly et al. [35] noted that the extreme quality silage can be achieved by mixing legumes and cereal crops throughout ensiling of forage.

4 Conclusions

Our findings revealed that application of organic fertilization, which improves the yield and quality characteristics of mixed crops. Organic fertilizer by the rate 35 m^3/ha improved the yield and quality characteristics of hay and silage in the barley-pea mixture. Compared with blackthorn crops, organic fertilizers are more valuable in the mixed planting of hay and silage. As a result of the present research on yield and quality parameters, the barley/pea mixture can be fertilized at 35 kg/m^3/ha to increase the yield and nutritional value of hay and silage.

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