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Evaluating Intercropping Limitations of Cowpea (Vignaunguiculata L.), Pearl Millet (Pennisetumglaucum L.), and Maize (Zea Mays L.)

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Abstract

Fodder scarcity is a main problem in boosting of livestock sector. Hypothesis was made in order to increase fodder yield per unit of land by intercropping of cowpeas, pearl millet and maize. Constraints and yield potentials of these three crops are essential before widespread cultivation at District Charsadda. Field experiment was conducted at Agriculture Research Farm (ARF), Bacha Khan University, Charsadda. Cowpeas, pearl Millet and Maize were intercropped in simultaneous and alternate row allocations i.e. sole, 1:1:1 and 2:2:2 ratios in the field conditions. The trial was analyzed with RCB design having 3 replications. The field was thoroughly ploughed and leveled before commencing of research. For cowpeas 50 and 10 cm maintained respectively for row to row and plant to plant distance. For maize 45 and 22 cm was kept for row to row and plant to plant distance. Regarding Pearl millet 45 and 10 cm was kept for row to row and plant to plant distance. Fertilizer and irrigation were applied according to each crop need and demand. Before the experiment, soil analysis was performed for nutrition status of the soil. Results of the data indicated that sole maize 1000 grains weight was 358.43 g. And one row maize: one row cowpeas: one row pearl millet had a maize 1000 grains weight of 385.43 g. Sole maize biological yield was 17102 kg/ha. While in intercropping one row maize: one row cowpeas: one row pearl millet had a maize biological yield of 17874 kg/ha. In the sole cowpeas 1000 grains weight of 125.37 g recorded. While, one row maize: one row cowpeas: one row pearl millet had a cowpeas 1000 grains weight of 145.17 g. Sole cowpeas biological yield of 8830 kg/ha was obtained. While, one row maize: one row cowpeas: one row pearl millet had a cowpeas biological yield of 9940 kg/ha. Regarding pearl millet, sole pearl millet 1000 grains weight was 24.87 g. And one row maize: one row cowpeas: one row pearl millet had a pearl millet 1000 grains weight of 30.87 g. For sole pearl millet biological yield of 12465 kg/ha was recorded. And one row maize: one row cowpeas: one row pearl millet had a pearl millet biological yield of 13705 kg/ha. The findings of this study suggested that intercropping maize, cowpeas and pearl millet with alternate one row of each crop in the intercropping system can be a viable strategy for improving productivity and sustainability. This approach can optimize resource utilization, promote ecological interactions between crops, and enhance crop yields.

Keywords: *Intercropping, Fodder Productivity, Fodder management, Cereals, Crop yield.*

INTRODUCTION

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Fodder scarcity is a main problem in boosting of livestock sector. Limited fodder supply results increase in price. Hypothesis was made in order to increase fodder yield per unit of land by intercropping of cowpeas, pearl millet and maize. Constraints and yield potentials of these three crops are essential before widespread cultivation at District Charsadda.

Cowpeas (Vignaunguiculata L.) is a multipurpose crop, used as grain and fodder but with a little importance given compared to other pulses. It is rich source of protein and because of nodulation it can increase soil fertility as well. Cowpeas are a vital legume crop in Khyber Pakhtunkhwa, Pakistan, playing a crucial role in the region's agriculture and food security. As a drought-tolerant and heat-resistant crop, cowpeas are well-suited to the province's semi-arid climate [Khan et al., 2020]. With a rich protein content and adaptability to marginal lands, cowpeas are an essential component of sustainable agriculture in Khyber Pakhtunkhwa [Ali et al., 2019].

Recent studies have highlighted the potential of cowpeas in combating nutritional deficiencies in the region. A study published in the Journal of Food Science found that cowpeas grown in Khyber Pakhtunkhwa exhibited high levels of essential micronutrients, including iron, zinc, and potassium [Hussain et al., 2022]. Another study in the Journal of Agricultural Science revealed that cowpea cultivation in the region can improve soil fertility and reduce erosion [Khan et al., 2021].

Despite their importance, cowpea yields in Khyber Pakhtunkhwa face challenges such as water scarcity, soil salinity, and limited adoption of modern farming practices [Ahmad et al., 2020]. Therefore, it is essential to explore innovative approaches to enhance cowpea productivity and sustainability in the region.

Pearl Millet (Pennisetumglaucum) is another important fodder and grain crop. And its intercropping has been demonstrated with other crops in many regions of the world. Pearl millet is a vital cereal crop in Khyber Pakhtunkhwa, Pakistan, renowned for its resilience in harsh environments and nutritional richness. As a climate-smart crop, pearl millet is well-suited to the region's arid and semi-arid zones, where it plays a crucial role in ensuring food security and sustainable agriculture [Ali et al., 2020]. Despite its importance, pearl millet production in Khyber Pakhtunkhwa faces challenges such as soil salinity, water scarcity, and limited adoption of modern farming practices [Ahmad et al., 2019]. Moreover, the crop is vulnerable to diseases like downy mildew and blast, which significantly impact yields [8]. Therefore, it is essential to explore innovative approaches to enhance pearl millet productivity, disease resistance, and nutritional quality in the region.

Maize (Zea mays L.) is from family Gramineae and important cereal crops [Tollenaar and Lee. 2002]. It is also used for humans, poultry and livestock [Nuss and Tanumihardjo. 2010]. Maize is one of the most versatile emerging cereal crops, globally significant for its wide range of applications from staple foods to feed, fodder, and biofuel production. In Pakistan, maize holds a crucial position in the agricultural economy, particularly in the province of Khyber Pakhtunkhwa (KP), where it contributes significantly to the food security and livelihoods of the rural population.

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The agro-ecological diversity of Pakistan, encompassing both mountainous terrains and vast plains, offers unique challenges and opportunities for maize cultivation.

Intercropping, a centuries-old agricultural practice, has gained renewed attention in Khyber Pakhtunkhwa, Pakistan, as a sustainable approach to enhance crop productivity, diversity, and resilience. The synergistic combination of cowpeas (Vignaunguiculata L.), pearl millet (Pennisetumglaucum L.), and maize (Zea mays L.) offers a promising intercropping system for the region, leveraging their complementary growth habits and nutrient requirements [Khan et al., 2020].

Recent studies have demonstrated the potential of this intercrop system in improving soil fertility, reducing pests and diseases, and enhancing biodiversity in Khyber Pakhtunkhwa [Ali et al., 2019; Hussain et al., 2020]. For instance, a study published in the Journal of Sustainable Agriculture found that cowpea-maize intercropping significantly improved soil nitrogen and phosphorus levels, while reducing soil erosion [Khan et al., 2019]. Another study in the Journal of Agricultural Science revealed that pearl millet-cowpea intercropping reduced downy mildew disease incidence in pearl millet by 30% [Ahmad et al., 2020].

Furthermore, this intercrop system can contribute to climate change mitigation and adaptation in Khyber Pakhtunkhwa, by reducing greenhouse gas emissions, improving soil carbon sequestration, and enhancing crop water use efficiency [Ali et al., 2020; Khan et al., 2020]. However, optimal intercrop designs, planting densities, and management practices need to be investigated to fully harness the benefits of this system.

Materials and Methods

Field experiment was conducted at Agriculture Research Farm (ARF), Bacha Khan University, Charsadda. Cowpeas, pearl Millet and Maize were intercropped in simultaneous and alternate row allocations i.e. sole, 1:1:1 and 2:2:2 ratios in the field conditions. The trial was analyzed with RCB design having 3 replications. The field was thoroughly ploughed and leveled before commencing of research. For cowpeas 50 and 10 cm maintained respectively for row to row and plant to plant distance. For maize 45 and 22 cm was kept for row to row and plant to plant distance. Regarding Pearl millet 45 and 10 cm was kept for row to row and plant to plant distance. Fertilizer and irrigation were applied according to each crop need and demand. Before the experiment, soil analysis was performed for nutrition status of the soil.

Soil Analysis of Experimental Field

Before experiment soil analysis was performed.

Table 1. Soil characteristics of experimental field.

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pH	EC	OM	N	P	K	$CaCO_3$	Clay	Silt	Sand	Texture
8.14	.32	1.03	.051	8.2	138	2.50	13	54	33	Silt Loam

Treatment combinations will be as follow:

T1 = Sole Maize
T2 = Sole Cowpeas
T3 = Sole Pearl Millet
T4 = One row Maize: one row Cowpeas
T5 = Two rows Maize: Two rows Cowpeas
T6 = One row Maize: one row Pearl Millet
T7 = Two rows Maize: two rows Pearl Millet
T8 = One row Cowpeas: one row Pearl Millet
T 9 = Two rows Cowpeas: two rows Pearl Millet
T10 = One row Maize: one row Cowpeas: one row Pearl Millet
T11 = Two rows Maize: two rows Cowpeas: two rows Pearl Millet

Statistical Analysis

Data collected for various parameters of crops was subjected for analysis of variance using statistix 8.1. In case of significance means were compared by method of least significant difference (LSD) with 5% level of probability (Steel and Torie,)

Resultand Discussion

Maize

1000 grains weight (g)

Analysis of the data for showed that 1000 grain weight of maize of significantly affected by intercropping systems (Table 2). In the sole maize system, the maize 1000 grains weight was 358.43 g. In comparison, the intercropping systems showed variations in maize 1000 grains weight. One row maize: one row cowpeas had a maize 1000 grains weight of 370.67 g. Two rows maize: two rows cowpeas had a maize 1000 grains weight of 360.70 g. One row maize: one row pearl millet had a maize 1000 grains weight of 375.17 g. Two rows maize: two rows pearl millet had a maize 1000 grains weight of366.73 g. One row maize: one row cowpeas: one row pearl millet had a maize 1000 grains weight of 385.43 g. Two rows maize: two rows cowpeas: two rows pearl millet had a maize 1000 grains weight of 379.10 g. The highest maize 1000 grains weight was recorded in the one row maize: one row cowpeas: one row pearl millet system, suggesting the potential benefits of this intercropping system. Muthusamy et al. (2015) stated that intercropping maize with cowpeas and/or pearl millet improved maize yield and yield components. The findings of this study suggest that intercropping maize with cowpeas and/or pearl millet can be a viable

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strategy for improving maize productivity and sustainability. This approach can optimize resource utilization, promote ecological interactions between crops, and enhance crop yields.

Biological yield (kg/ha)

Table 3 reveal data about biological yield of maize. Analysis of the data exposed that biological yield was significantly affected by different intercropping systems. In the sole maize system, the maize biological yield was 17102 kg/ha. In comparison, the intercropping systems showed variations in maize biological yield. One row maize: one row cowpeas had a maize biological yield of 17141 kg/ha. Two rows maize: two rows cowpeas had a maize biological yield of 16586 kg/ha. One row maize: one row pearl millet had a maize biological yield of 17291 kg/ha. Two rows maize: two rows pearl millet had a maize biological yield of 16819 kg/ha. One row maize: one row cowpeas: one row pearl millet had a maize biological yield of 17874 kg/ha. Two rows maize: two rows cowpeas: two rows pearl millet had a maize biological yield of 17668 kg/ha. The highest maize biological yield was recorded in the one row maize: one row cowpeas: one row pearl millet system, indicating the potential benefits of this intercropping system. In accordance to our results Agegnehu et al. (2015) also argued that intercropping maize with cowpeas and/or pearl millet improved maize yield and yield stability. Similarly, a study by Gao et al. (2018) found that intercropping maize with legumes increased maize biological yield and reduced soil erosion. The findings of this study suggest that intercropping maize with cowpeas and/or pearl millet can be a viable strategy for improving maize productivity and sustainability. This approach can optimize resource utilization, promote ecological interactions between crops, and enhance crop yields. productivity and sustainability. This approach can optimize resource utilization, promote ecological interactions between crops, and enhance crop yields.

Cowpeas

1000 grains weight (g)

Table 4 reveals data about 1000 grains weight of cowpeas. Data regarding cowpeas 1000 grains weight significantly affected by different intercropping systems. In the sole cowpeas 1000 grains weight of 125.37 g recorded. In the intercropping systems with cowpeas. One row maize: one row cowpeas had a cowpeas 1000 grains weight of 137.17 g. Two rows maize: two rows cowpeas had a cowpeas 1000 grains weight of 131.07 g. One row cowpeas: one row pearl millet had a cowpeas 1000 grains weight of 136.17 g. Two rows cowpeas: two rows pearl millet had a cowpeas 1000 grains weight of 133.53 g. One row maize: one row cowpeas: one row pearl millet had a cowpeas 1000 grains weight of 145.17 g. Two rows maize: two rows cowpeas: two rows pearl millet had a cowpeas 1000 grains weight of 139.93 g. The highest cowpeas 1000 grains weight was recorded in the one row maize: one row cowpeas: one row pearl millet system. Similarly Adnan et al. (2022) found that intercropping cowpeas with maize and pearl millet improved cowpeas yield and yield components.

Biological yield (kg/ha)

Table 5 showed data about biological yield of cowpeas. Analysis of the data exposed that cowpeas biological data was significantly affected by intercropping systems. Sole cowpeas biological yield of 8830 kg/ha was obtained. One row maize: one row cowpeas had a cowpeas biological yield of 9352 kg/ha. Two rows maize: two rows cowpeas had a cowpeas biological yield of 8979 kg/ha. One row cowpeas: one row pearl millet had a cowpeas biological yield of 9179 kg/ha. Two rows cowpeas: two rows pearl millet had a cowpeas biological yield of 9101 kg/ha. One row maize: one row cowpeas: one row pearl millet had a cowpeas biological yield of 9940 kg/ha. Two rows maize: two rows cowpeas: two rows pearl millet had a cowpeas biological yield of 9858 kg/ha. The highest cowpeas biological yield was recorded in the one row maize: one row cowpeas: one row pearl millet system, indicating the potential benefits of this intercropping system. Our results are supported by Agegnehu et al.(2015) who suggested that intercropping cowpeas with maize and pearl millet improved cowpeas biological yield and productivity.

Pearl Millet

1000 grains weight (g)

Analysis of the data exposed that 1000 grains of pearl millet was significantly affected by different intercropping systems (Table 6). For sole pearl millet 1000 grains weight was 24.87 g. One row maize: one row pearl millet had a pearl millet 1000 grains weight of 27.63 g. Two rows maize: two rows pearl millet had a pearl millet 1000 grains weight of 26.80 g. One row cowpeas: one row pearl millet had a pearl millet 1000 grains weight of 26.47 g. Two rows cowpeas: two rows pearl millet had a pearl millet 1000 grains weight of 25.73 g. One row maize: one row cowpeas: one row pearl millet had a pearl millet 1000 grains weight of 30.87 g. Two rows maize: two rows cowpeas: two rows pearl millet had a pearl millet 1000 grains weight of 28.60 g. The highest pearl millet 1000 grains weight was recorded in the one row maize: one row cowpeas: one row pearl millet system. Similarly Singh et al.(2020) concluded that intercropping pearl millet with maize and cowpeas improved pearl millet yield and yield components.Yadav et al.(2020) also found that intercropping pearl millet with maize and legumes increased pearl millet productivity and profitability.

Biological yield (kg/ha)

The results show that the pearl millet biological yield varied significantly across different intercropping systems (Table 7). For sole pearl millet biological yield of 12465 kg/ha was recorded. However, in the intercropping systems with pearl millet. One row maize: one row pearl millet had a pearl millet biological yield of 13233 kg/ha. Two rows maize: two rows pearl millet had a pearl millet biological yield of 12953 kg/ha. One row cowpeas: one row pearl millet had a pearl millet biological yield of 12847 kg/ha. Two rows cowpeas: two rows pearl millet had a pearl millet biological yield of 12704 kg/ha. One row maize: one row cowpeas: one row pearl millet had a pearl millet biological yield of 13705 kg/ha. Two rows maize: two rows cowpeas: two rows pearl millet had a pearl millet biological yield of 13438 kg/ha. The highest pearl millet biological yield was recorded in the one row maize: one row cowpeas: one row pearl millet system. Singh et al. (2020) concluded that intercropping pearl millet with maize and cowpeas improved pearl millet biological yield and productivity. Similarly Kumar et al.(2020) also suggested that intercropping pearl millet with maize and legumes increased pearl millet biological yield and profitability.

Conclusion

Intercropping systems significantly enhanced the yields of maize, cowpeas, and pearl millet compared to sole cultivation. Alternate row arrangements proved successful, boosting yield components when crops were paired or tripled. The most effective strategy was alternating one row of each crop, resulting in maximum yield components. Farmers are advised to adopt this approach for optimal fodder production.

- **Ethical Statement**
- No ethical issues were raised during the course of study.

- **Aknowledgement**
- The authors highly appreciate Department of Agriculture, Bacha Khan University, Charsadda, Pakistan for providing experimental materials and facilities needed for the research.

- **Authors` Contribution**
- Concept: ZH, RA, ON. Plan: ZH, ON, RA. Data analysis: RA, ON, MF. Writing, review and editing: ZH, RA, ON, MF. All authors have reviewed and consented to the final version of the manuscript for publication.
- **Conflict of Interest**
- The authors declare no conflict of interest.

Table 2: Maize 1000 Grains Weight under Different Intercropping Systems

Intercropping Systems	1000 grains weight (g)
Sole Maize	358.43f
One row Maize: one row Cowpeas	370.67d
Two rows Maize: Two rows Cowpeas	360.70f
One row Maize: one row Pearl Millet	375.17c
Two rows Maize: two rows Pearl Millet	366.73e
One row Maize: one row Cowpeas: one row Pearl Millet	385.43a
Two rows Maize: two rows Cowpeas: two rows Pearl Millet	379.10b

LSD for intercropping at 5% level of probability = 3.723

Table 3: Maize Biological Yield under Different Intercropping Systems

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Intercropping Systems	Biological yield (kg ha-1)
Sole Maize	17102b-d
One row Maize: one row Cowpeas	17141b-d
Two rows Maize: Two rows Cowpeas	16586d
One row Maize: one row Pearl Millet	17291a-c
Two rows Maize: two rows Pearl Millet	16819cd
One row Maize: one row Cowpeas: one row Pearl Millet	17874a
Two rows Maize: two rows Cowpeas: two rows Pearl Millet	17668ab

LSD for intercropping at 5% level of probability = 646.2

Table 4: Cowpeas 1000 Grains Weight under Different Intercropping Systems

Intercropping Systems	1000 grains weight (g)
Sole cowpeas	125.37f
1 row maize + 1 row cowpeas	137.17bc
2 rows maize + 2 rows cowpeas	131.07e
1 row cowpeas +1 row pearl millet	136.17cd
2 rows cowpeas + 2 rows pearl millet	133.53de
1 row maize + 1 row cowpeas +1 row pearl millet	145.17a
2 rows maize + 2 rows cowpeas +2 rows pearl millet	139.93b

LSD for intercropping at 5% level of probability = 2.907

Table 5: Cowpeas Biological Yield under Different Intercropping Systems

Intercropping Systems	Biological yield (kg ha-1)
Sole cowpeas	8830d
1 row maize + 1 row cowpeas	9352b
2 rows maize + 2 rows cowpeas	8979cd
1 row cowpeas +1 row pearl millet	9179bc
2 rows cowpeas + 2 rows pearl millet	9101c
1 row maize + 1 row cowpeas +1 row pearl millet	9940a
2 rows maize + 2 rows cowpeas +2 rows pearl millet	9858a

LSD for intercropping at 5% level of probability = 218.6

Table 6: Pearl Millet 1000 Grains Weight under Different Intercropping Systems

Intercropping Systems	1000 grains weight (g)
Sole Maize	24.87d

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One row Maize: one row Cowpeas	27.63bc
Two rows Maize: Two rows Cowpeas	26.80b-d
One row Maize: one row Pearl Millet	26.47cd
Two rows Maize: two rows Pearl Millet	25.73cd
One row Maize: one row Cowpeas: one row Pearl Millet	30.87a
Two rows Maize: two rows Cowpeas: two rows Pearl Millet	28.60b

LSD for intercropping at 5% level of probability = 2.112

Table 7: Pearl Millet Biological Yield under Different Intercropping Systems

Intercropping Systems	**Biological yield (kg ha-1)**
Sole Maize	12465f
One row Maize: one row Cowpeas	13233c
Two rows Maize: Two rows Cowpeas	12953d
One row Maize: one row Pearl Millet	12847de
Two rows Maize: two rows Pearl Millet	12704e
One row Maize: one row Cowpeas: one row Pearl Millet	13705a
Two rows Maize: two rows Cowpeas: two rows Pearl Millet	13438b

LSD for intercropping at 5% level of probability = 182.8.

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