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# Study of Intercropping Agroecosystem Productivity Influenced by Different Crops and Planting Ratios

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**Abstract:** Intercropping system of cereal with legume or some non-legume is a common practice in many developing countries because it may produce higher forage quantity and quality product than monocropping. The objective of this study was to evaluate the effects of mixture system and planting ratios on forage yield and yield components of two intercropping systems including maize:amaranth and maize:mungbean. This field study was conducted during 2008-09 under Mediterranean region in Ahvaz, Iran. The experimental design was split plot with three replications. Our results showed that both intercropping systems at the 75:25 mix-proportion had the highest intercropping dry matter yield. However, regardless of planting ratios, maize:amaranth had the highest intercropping dry matter. But, maize:mungbean at this condition was observed to be the most LER advantages. Furthermore, greater dry matter in maize:amaranth intercropping system mainly was due to higher leaf weight and stem weight values in this mixture than maize:mungbean system. Means stem and leaf weights were higher in maize:amaranth than maize:mungbean mixture. However, yield of all maize intercropping systems were less than it was in monocropping. The ratio of proportion also seemed to had significantly affect on yield components of both intercropping systems and all crops. Despite of maize dry matter decrease in intercropping system as compared to sole stand, mixing of legume or some pseudocereal in cereal is a suitable alternative to increase the quality of cereal fodders.

**Keywords:** Intercropping system · Planting ratios · Forage · Land equivalent ratio · Dry matter

## INTRODUCTION

Intercropping cereals with legumes is usually done to maximize productivity in many part of the Mediterranean region. This practice, simultaneously growing crops together in field, often increase the total crop yield above that of its components when grown separately [1]. One of the main reasons for higher yields in intercropping is that component crops are able to use growth resources differently and make better overall use of natural resources than grown separately [2]. Traditionally, in the Mediterranean region, mixtures of certain legumes with cereals are used extensively for forage production [3]. This may be due to some of the established and speculated advantages for intercropping systems such as higher yields, greater land-use-efficiency and improvement of soil fertility through the addition of nitrogen by fixation and excretion from the component legume [4].

In fact, yield advantages occur when intercrop components compete only partly for the same plant growth resources. Thus, when the interspecific competition is less than intraspecific competition [5]. Ideally, crops or cultivars is suitable for intercropping should enhance the complementary effects between species [6]. The productivity of an intercrop is affected by yield trade-offs among component crops, which are in turn affected by elements such as plant stature, plant population (i.e. plant ratios in mixture) and planting date. In intercrops of tall $C_4$ cereals with shorter legumes, the cereal is usually the aggressor and depending on plant population, causes large yield reduction in the associated crop [5, 7].

In maize based intercropping system, selection of an appropriate intercrop having desirable plant type and growth pattern assumes greater importance. Crops maturing well before the peak growth period of maize are ideal. Other studies on intercropping has indicated how

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niche differences in crop species can lead to resource capture and conversion leading to increased biological efficiency and yield advantage [8, 9, 10].

Intercropping cereals with legumes increases protein content of forage compared with growing cereal alone. In contrast, intercropping cereal with non-legume although are seldom sown in this region [11], But it had increased dry matter production in some instances [12, 13]. Both quality and quantity of fodder are influenced due to plant species [14]. Work done by Izaurralde *et al.* [15] suggested that no yield advantage resulted when barley and pea were intercropped at a sole crop rate compared with lower rates in barley-pea mixtures; however, nitrogen yield was increased by intercropping when both barely and pea were sown at more than half the sole crop rate. Moreover, mixing of legumes in cereals is a better choice to increase the quality of cereal fodders. It has been reported that dry matter yields of maize alone were greater than soybean intercropping. However, intercropping gave higher crud protein yields than maize alone [16].

Therefore, this study was conducted to determine how intercropping forage yield and yield component was affected when the cereal, pseudoecereal and legume are sown at a different combinations and planting ratios in a mixture.

## MATERIALS AND METHODS

A field experiment was conducted at Agricultural Faculty of Shahid Chamran University, Ahwaz, Iran, under Mediterranean condition during 2008-09. The experimental site is located at 20 m above sea level, had an average rainfall of 360 mm with 31°20× N latitude and 48°41× E longitudes, average summer and winter temperature 39 and 3°C, respectively. The soil properties before planting were sandy loam texture, pH, 7.7; organic C, 0.54%; total N, 0.49%; available P, 14 mg $kg^{-1}$ and exchangeable K, 160 mg $kg^{-1}$.

A randomized complete block design in a split-plot arrangement was used. Two intercropping systems (i.e. Maize:Amaranth and Maize:Mungbean) constituted the main plots and five planting ratios (i.e. 0, 25, 50, 75 and 100%) constituted the sub plots. Blocks were replicated three times. Sub plot dimensions were 6 by 4 m (24 $m^2$). All crops in each intercropping system were planted in alternative rows and arranged in replacement series. The inter-row spacing was 75 cm and the intra-row plant spacing for maize, amaranth and mungbean were 15, 15 and 7.5 cm, respectively. The same planting density of 90,000 plant $ha^{-1}$ was maintained based on maize plant density. Thus, the plant equivalent for maize:amaranth was 1:1 and for maize:mungbean was 1:2 in each intercropping system. The maize (cv. S.C. 704), amaranth (cv K 283) and mungbean (cv. Hendi) were planted at the same day on 18 July at their appropriate planting ratios depending on the treatments. Seedbed preparation included ploughing, disk harrowing and cultivation. Nitrogen, $P_2O_5$ and $K_2O$ at 70-50-30 N-P-K were application as urea and superphosphate. Crops in monocultures and in mixtures were harvested in a randomly selected 4 $m^2$ area of each plot by hand harvesting at the milk stage (R3 stage: 18-22 days after silking) of maize. Samples of each crop were separated for the determination of plant leaf and stem weight in each mixture. Crop weight ratios (i.e. leaf/stem, leaf/total and stem/total), total dry matter and plant height were measured. Crop dry matter dried at 60°C for 48 hours. The land equivalent ratio (LER) was calculated as follows [5]:

$$LER = (LER_a + LERb)$$
$$LER_a = (Y_{ab} / Y_a)$$
$$LER_b = (Y_{ba} / Y_b)$$

Where Y is the yield of each crop, a is maize and b is mungbean or amaranth crop, respectively.

Data were subjected to analysis of variance (ANOVA) using the SAS statistical software programme. The values are means of the two growing seasons. Treatment means were compared with Duncan's multiple range test.

## RESULTS

**Leaf Weight:** The maize leaf weight had higher values in the all maize:amaranth intercropping system ratios than the maize:mungbean intercropping system. The highest maize leaf weight value was obtained from 75 maize:25 amaranth mixture, while the lowest was from 25 maize:75 mungbean (Table 1). Comparing two intercropped maize showed that maize in maize:amaranth mixture had the highest means leaf weight value than in maize:mungbean intercropping system (Table 1). There were a 28, 25 and 0.09% increase in total leaf weight in the maize:amaranth intercropping system for 25:75, 50:50 and 75:25 planting ratios in compared with sole maize cropping system, respectively. The mean total leaf weight of the maize:amaranth intercropping system was higher than maize:mungbean mixture (Table 1), indicating an advantage of this intercropping system.

Table 1: Effect of different intercropping systems and planting ratios on leaf weight and stem weight

| | Leaf weight (g m$^2$) | | | | Shoot weight (g m$^2$) | | | |
|---|---|---|---|---|---|---|---|---|
| Planting ratio (%) | Maize | Amaranth | Mungbean | Total | Maize | Amaranth | Mungbean | Total |
| Maize:Amaranth | | | | | | | | |
| 0-100 | --- | 566.44 | --- | 566.44 a | --- | 708.10 | --- | 708.10 f |
| 25-75 | 146.78 | 407.10 | --- | 553.89 a | 743.98 | 498.68 | --- | 1242.7 cd |
| 50-50 | 213.56 | 317.16 | --- | 530.72 a | 1098.13 | 358.32 | --- | 1456.4 bc |
| 75-25 | 294.75 | 140.53 | --- | 435.28 bc | 1493.33 | 152.64 | --- | 1645.9 ab |
| 100-0 | 396.35 | --- | --- | 396.35 c | 1862.3 | --- | --- | 1862.3 a |
| Maize:Mungbean | | | | | | | | |
| 0-100 | --- | --- | 319.74 | 319.74 d | --- | --- | 272.5 | 272.5 g |
| 25-75 | 123.76 | --- | 435.45 | 559.21 a | 567.71 | --- | 390.79 | 958.5 e |
| 50-50 | 199.51 | --- | 219.35 | 418.86 bc | 883.42 | --- | 201.42 | 1084.84 de |
| 75-25 | 280.50 | --- | 186.54 | 467.04 b | 1311.06 | --- | 164.27 | 1475.3 bc |
| 100-0 | 396.35 | --- | --- | 396.35 c | 1862.3 | --- | --- | 1862.3 a |
| Means Maize:Amaranth | 262.86 | 357.81 | --- | 496.54 | 1299.44 | 429.44 | --- | 1383.08 |
| Means Maize:mungbean | 250.03 | --- | 290.27 | 432.24 | 1156.12 | --- | 257.25 | 1130.69 |

Means in a column with the same letter are not significantly different at $P$=0.05

Table 2: Different crop parts weight ratios as influenced by intercrops and planting ratios

| | Leaf / total ratio | | | | Leaf / stem ratio | | | | Stem / Total ratio | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planting ratio(%) | M* | A | Mb | Total | M | A | Mb | Total | M | A | Mb | Total |
| Maize:Amaranth | | | | | | | | | | | | |
| 0-100 | --- | 0.44 | --- | 0.44 b | --- | 0.79 | --- | 0.79 b | --- | 0.55 | --- | 0.55 g |
| 25-75 | 0.082 | 0.226 | --- | 0.308 d | 0.12 | 0.33 | --- | 0.45 d | 0.41 | 0.28 | --- | 0.69 e |
| 50-50 | 0.107 | 0.159 | --- | 0.226 e | 0.15 | 0.22 | --- | 0.37 ef | 0.55 | 0.18 | --- | 0.73 d |
| 75-25 | 0.142 | 0.067 | --- | 0.21 g | 0.18 | 0.08 | --- | 0.26 gh | 0.72 | 0.07 | --- | 0.79 b |
| 100-0 | 0.17 | --- | --- | 0.17 h | 0.21 | --- | --- | 0.21 h | 0.82 | --- | --- | 0.82 a |
| Maize:mungbean | | | | | | | | | | | | |
| 0-100 | --- | --- | 0.54 | 0.54 | --- | --- | 1.17 | 1.17 a | --- | --- | 0.46 | 0.46 h |
| 25-75 | 0.081 | --- | 0.287 | 0.368 c | 0.13 | --- | 0.45 | 0.58 c | 0.37 | --- | 0.26 | 0.63 f |
| 50-50 | 0.132 | --- | 0.145 | 0.277 e | 0.18 | --- | 0.20 | 0.38 e | 0.59 | --- | 0.13 | 0.72 d |
| 75-25 | 0.144 | --- | 0.096 | 0.24 f | 0.19 | --- | 0.13 | 0.32 fg | 0.67 | --- | 0.08 | 0.75 c |
| 100-0 | 0.17 | --- | --- | 0.17 h | 0.21 | --- | --- | 0.21 h | 0.82 | --- | --- | 0.82 a |
| Means Maize:Amaranth | 0.125 | 0.223 | --- | 0.271 | 0.16 | 0.36 | --- | 0.42 | 0.63 | 0.27 | --- | 0.72 |
| Means Maize:mungbean | 0.132 | --- | 0.267 | 0.319 | 0.18 | --- | 0.49 | 0.53 | 0.61 | --- | 0.23 | 0.68 |

Means in a column with the same letter are not significantly different at $P$=0.05

*M: Maize, A: Amaranth, Mb: Mungbean

**Stem Weight:** The total stem weight affirmed that all maize:amaranth intercropping ratios had higher values than maize:mungbean mixtures. Also, partials maize stem weight were higher in all maize:amaranth planting ratios than maize:mungbean mixture. The highest and lowest total stem weight values were obtained by maize sole cropping and maize:mungbean intercropping system at 25:75 planting ratio, respectively. The highest total intercropped stem weight value of 1645.9 g m$^2$ showed that this mixture lead to highest mixture dry matter (i.e. 2081.2 g m$^2$) than others mainly due to maize stem weight. Also, mean total stem weight showed that the maize:mungbean intercropping had significantly lower total stem weight value than maize:amaranth mixture (Table 1).

**Crop Parts Weight Ratios:** The leaf/total ratio value for both amaranth and mungbean were the most at 25:75 planting ratio with maize. As expected, leaf/total ratio of amaranth and mungbean decreased as the proportion of maize increased in mix-proportions (Table 2). Comparison among the means of total leaf/total ratio values showed

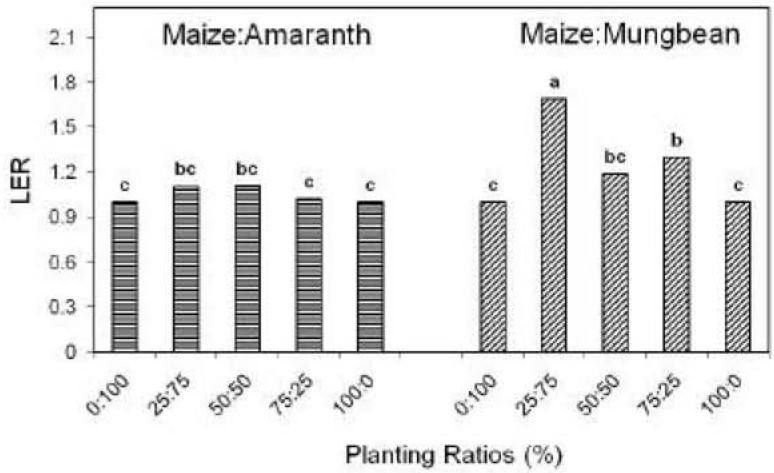


**Fig. 1: Comparison of total LER in both intercropping systems**

Table 3: Total dry matter and plant heights of crops in intercropping systems and planting ratios

| | Plant height (cm) | | | Total dry matter (g m$^2$) | | | |
|---|---|---|---|---|---|---|---|
| Planting ratio(%) | Maize | Amaranth | Mungbean | Maize | Amaranth | Mungbean | Total |
| Maize:Amaranth | | | | | | | |
| 0-100 | --- | 145.57 | --- | --- | 1274.54 | --- | 1274.54 d |
| 25-75 | 202.1 | 151.03 | --- | 890.77 | 905.78 | --- | 1796.5 c |
| 50-50 | 207.3 | 144.73 | --- | 1311.69 | 675.48 | --- | 1987.2 abc |
| 75-25 | 210.3 | 126.06 | --- | 1788.08 | 293.17 | --- | 2081.2 ab |
| 100-0 | 209.83 | --- | --- | 2258.6 | --- | --- | 2258.6 a |
| Maize:mungbean | | | | | | | |
| 0-100 | --- | --- | 43 | --- | --- | 592.3 | 592.3 e |
| 25-75 | 206.83 | --- | 62 | 691.47 | --- | 826.25 | 1517.72 d |
| 50-50 | 203.43 | --- | 55 | 1082.94 | --- | 420.76 | 1503.7 d |
| 75-25 | 212.23 | --- | 50 | 1591.56 | --- | 350.81 | 1942.4 bc |
| 100-0 | 209.83 | --- | --- | 2258.6 | --- | --- | 2258.6 a |
| Means Maize:Amaranth | 207.38 | 141.85 | --- | 1562.28 | 787.24 | --- | 1879.608 |
| Means Maize:mungbean | 208.08 | --- | 52.5 | 1406.14 | --- | 547.53 | 1562.94 |

Means in a column with the same letter are not significantly different at $P$=0.05

that the intercropped mungbean had higher leaf/total ratio than the intercropped amaranth in the mixture with maize (Table 2). When the maize was lower than 50%, the maize leaf/total ratio had lower value (Table 2). The maize leaf/total ratios were higher than one in both intercropping systems at the 50:50 and 75:25 planting ratios. In addition, amaranth and mungbean in monocropping system had the higher leaf/total ratio than all mixtures (Table 2).

In all planting ratios, maize and mungbean sole cropping had the highest and lowest total leaf/stem ratio, respectively. Moreover, in both intercropping systems, total leaf/stem ratio values were decreased as the proportion of maize increased in mixtures (Table 2). However, maize:mungbean mixtures had a higher means leaf/stem ratio than the maize:amaranth intercropping system. The stem/total ratio for the sole maize system was significantly ($P < 0.05$) greater than any of the other monocropping and mixtures (Table 2). The maize crop in both intercropping systems had a fairly the same stem/total ratio values. In addition, there were significant differences between the two intercropping systems in their means stem/total ratio values. However, the maize: mungbean intercropping system generally had lower stem/total ratio than maize:amaranth intercropping.

**Plant Height:** Intercropped and sole cropping maize had a same plant height in maize:amaranth mixture and maize:mungbean intercropping systems at all planting ratios, indicating that maize was non-affected by

associated crop in these intercropping Systems (Table 3). However, mungbean had lower plant height in sole system than in mixture with maize, indicating the significant effect of competition under crop mixture. This clearly shows that in some mixtures, mungbean was more competitive for some resource (i.e. light) than the maize crop (Table 3). In maize:amaranth intercropping system, the plant height of amaranth significantly ($P < 0.05$) was decreased as the proportion of amaranth decreased in the mixture. Moreover, the mean values of plant height for maize were the same between two intercropping systems. The corresponding value of plant height for sole amaranth was also lower than amaranth in maize:amaranth mixture at 75:25 planting ratio. This indicates that maize was more competitive as amaranth in this mixture.

Total Dry Matter: The highest intercropped maize forage yield was obtained from 75 maize: 25 amaranth mixture, while the lowest one was 25 maize:75 mungbean mixture. The highest intercropped amaranth and mungbean forage yield was from 25:75 planting ratio and the lowest one was from 75:25 mixture (Table 3). In maize:amaranth intercropping system, forage yield was higher by (10%) than that in maize:mungbean intercropping system. All mixture of amaranth with maize (i.e. 25, 50 and 75% planting ratios), however, produced about 28, 36 and 39%, respectively, more forage yield than the monoculture amaranth, but about 20, 12 and 7%, respectively, less than the monoculture maize (Table 3). A similar trend also was observed for mungbean in maize:mungbean intercropping system.

**Land Equivalent Ratio (LER):** Difference among intercropping systems and crops were significant ($P < 0.05$) for LERs. Forage yield was lower but total LER was higher for the maize:mungbean than for the maize:amaranth intercropping systems (Table 3 and Figure 1). Partial LER was higher for maize at 75:25 planting ratio in both intercropping systems than other proportions. In addition, the partial LERs of amaranth in mixture with maize at all ratios were lower than that of mungbean (data not shown).

## DISCUSSION

Our results showed that about 42 and 69% decrease in leaf weight of mungbean and maize in maize:mungbean intercropping system (at lower planting ratio), respectively, when compared to their sole each crop leaf weight. In all planting ratios, the magnitude of amaranth mean leaf weight that is greater than maize mean leaf weight indicated that amaranth had more leaf than mungbean in intercropped with maize. The maize leaf weight had lower values in both intercropping at all maize proportions (Table 1), indicating a quantity disadvantage of intercropped maize over sole stand. Although, the partial leaf weights of maize, were fairly the same in both intercropping systems, but maize:amaranth mixture system had higher leaf weight than maize:mungbean mixture, indicating a quality advantage of this intercropping system. These results are in line with that founded by other researchers [6, 17, 2].

The intercropping stem weight confirmed that all mixtures had higher stem weight values over sole stand of each crop, which showed definite intercropping advantages compared to the sole cropping systems. The highest intercropping stem weight values was obtained in maize:amaranth at 75:25 ratio (1645.9), which was lower than maize sole stand. Some studies also reported the effect of different intercropping systems and crop species on stem and shoot weight [18, 5, 11, 1].

The leaf/total ratio and leaf/stem ratio values for maize:mungbean intercropping system were much higher than maize:amaranth intercropping system, indicating a quality advantages of mungbean over the amaranth in all planting ratios. This result was appeared that maize had more stem/total ratio than amaranth and mungbean crops. However, stem/total values for maize were the same in both intercropping systems, indicating that amaranth had not more influence than mungbean in mixture with maize. These results were similar as that reported by Al-Dalain [19], Hiebsch *et al.* [16] and Mpairwe *et al.* [3].

Considering all mix-proportions and intercropping systems, maize plant height values were higher than amaranth and mungbean, showing that maize was the dominant species in maize:amaranth and maize:mungbean intercropping systems. Nevertheless, the maize plant height was the same in both intercropping systems. Moreover, increasing the maize ratios in mixtures changed the plant height of amaranth and mungbean, which probably resulted in higher maize intercompetition effects. In addition, mungbean plant height was more affected than amaranth in intercropped with maize. In this situation, when planting ratios were changed mungbean became more competitive associated crop with maize than amaranth. Effect of different mixtures on plant height also reported by Ghosh [8], Hugar and Palled [20], Lingaraju *et al.* [21] and Muoneke and Asiegbu [7].

The results showed that the sole cropping of maize yielded higher than did all the maize:amaranth and maize:mungbean combinations. Although, such mixtures

indeed increased the intercropping yield of amaranth and mungbean than sole crop (Table 1). In some cases, it has been reported that total dry matter of mixtures of legumes and cereals were intermediate or even lower than yields of monocultures due to competition between species [18]. Ghosh [8] reported that monoculture production of cereal fodder or groundnut yielded higher than in the intercropped culture. This was partly the result of the highest plant population in the monocrops. Also, the crop did not experience inter-specific competition. Ghaley *et al.* [17] reported that legume-cereal intercrops reduce their advantage over sole crops in the case where N fertilizers are applied, reducing the inter-specific complementarily, often reported as reducing the proportion of legumes in the total harvested intercrop yield. Therefore, competition for nutrients and light in intercropping system is often interrelated, particularly for legume/non-legume crop combinations [9]. In general, under growing conditions where cereal sole crops produce rather high yields, intercropping with legumes has no advantages over cereal sole crops [11]. However, when evaluated over a number of years the intercrops are expected to show more stable yields than the specific sole crops [22].

Hiebsch *et al.* [16] and Lauk and Lauk. [11] found that when non legume crop was grown in associated with legumes, irrespective of the specific combination, the Non legume crop benefited with respect to the proportionate yield of its sole crop. This can be attributed to the complementary effect of legume association through nutrient transfer. The results also showed that the pure stand of crops maintained supremacy over the intercropping system with respect to economic yield, which may be due to limited disturbance of the habitat and interactional competition in the sole cropping environment.

The land equivalent ratio indices were the greatest in maize:mungbean (1.69) in the 25:75 mix-proportion. Also, this proportion had the highest maize:mungbean intercropping dry matter than others. This indicating that 69% more area would be required for solitary cropping system compared to intercropping. Midya *et al.* [13] reported that greater intercrop yield advantage from total intercropping system LER values higher than one were indicating the advantage of mixtures over sole stands in regard to the use of agro-environmental sources for plant growth. In this case, total LER was significantly different from 1.00, which shows an advantage from intercropping over pure stands in terms of the use of environmental resources for plant growth. On the other hand, total LERs below 1.00 were not found in the cases of all intercropping systems, which show an advantage of these mixtures over each crop pure stands. Similar results were reported for different proportion of plant in mixtures by Agegnehu *et al.* [18], Hauggaard-Nielsen *et al.* [22], Lithourgidis *et al.* [1] and Mucheru-Muna *et al.* [9].

Hauggaard-Nielsen and Jensen [23] reported that the LER values showed that in the intercrop plant growth resources were used on average 20% more efficient without N application and 5-10% more efficient with N application. Also, this effect was observed in term of the decrease partial and total legumes LER values when N was applied. Because of application of N caused a dynamic change in the intercrop composition and thereby competitive ability of each crop in mixtures for other resources [6, 12, 10].

## CONCLUTIONS

The present study revealed that intercropping of maize with amaranth and mungbean in different planting ratios had influenced on total dry matter, plant height and leaf and stem weights on all crops. As compared to sole cropping of the each crop, the maize:amaranth mixture had a best intercropping total dry matter, leaf weight and stem weight values. But, the maize: mungbean mixture had a best LER advantageous. Furthermore, higher dry matter of maize:amaranth mixture than maize:mungbean mainly was due to greater maize stem weight in this mixture than other. Yield of all maize intercroppings were less than it was in monocropping. However, results obtained from LER of the maize:amaranth and maize:mungbean mixtures indicated a significant advantage from maize intercropping than the sole cropping system. Despite of maize dry matter decrease in intercropping system as compared to sole stand, mixing of legume in cereals is a suitable alternative to increase the quality of cereal fodders.

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