

Pearl millet Based Cropping Systems in Relation to Plant Population and Moisture Availability

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Abstract: Intercropping systems and plant population effects were assessed under moisture sufficiency and stress situations. The mean index of moisture adequacy (MI_{ma}) during juvenile, vegetative and reproductive phases was 0.77, 0.85 and 0.78, respectively, in a moisture-sufficient season, and 0.64, 0.41 and 0.25 under moisture stress season. Row intercropping of pearl millet - clusterbean (1:1) and strip cropping (4:4) with 50% of the sole pearl millet population produced only 16.6 and 35.4% lower yield in a moisture-sufficient season, and 35.3 and 37.4% lower yield in moisture stress season. Non-proportional yield reductions in pearl millet due to change in plant populations were attributed to border effects. A moderate population of 88,888 plants ha⁻¹ (equal proportion of pearl millet and clusterbean) was optimum for row intercropping (1:1) and strip cropping (4:4) in moisture-sufficient season, and low (40,000 plants ha⁻¹) to moderate populations produced satisfactory yields in moisture stress season. Intercropping systems used 8-14 mm more water compared to sole pearl millet, but the improvement in water-use-efficiencies were conspicuous, more so in a moisture stress season.

Key words: Intercropping, pearl millet, clusterbean, plant population, water use, water-use-efficiency.

Pearl millet [*Pennisetum glaucum* (L.) R.Br.] is the most important crop of arid and semi-arid regions. It is grown as sole or as mixed/intercrop with annual legumes and oilseed crops. Intercropping of pearl millet and legumes, however, was more advantageous than mixtures (Singh and Joshi, 1994a). Efficient use of resources is one of the reasons for better yields in intercropping. Comparison of intercropping in replacement and additive series further suggests that more advantages could be realized by growing these crops in replace-

ment series, as vegetative and reproductive stages of component crops are nearly concurrent (Singh and Joshi, 1994b). Intercropping has been advocated for environments where water stress is likely to occur (Morris and Garrity, 1993). In most cases WU by sole and intercrops differed only slightly but the improvements in water-use-efficiency (WUE) and crop productivity were conspicuous (Morris *et al.*, 1990). Natarajan and Willey (1980 a,b) showed that variation of either crop component densities in intercropping system affected WUE and yield. Rees (1986) attributed large negative WUE and yield changes to severe terminal water stress

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brought about by early water extraction from limited supply. The present study, therefore, aims to optimize plant population of pearl millet-clusterbean intercropping, common in arid zone.

Materials and Methods

Sole, row and strip cropping with four plant populations were assessed under moisture sufficiency and stress situations at Central Arid Zone Research Institute, Jodhpur. The soil of experimental site was loamy sand in texture (80.9% sand, 7.21% silt, 11.9% clay), poor in organic matter (0.4%), and medium in available P (17 kg ha⁻¹) and K (190 kg ha⁻¹). Treatments consisted of three cropping systems, viz., sole cropping of pearl millet, row intercropping of pearl millet and clusterbean [*Cyamopsis tetragonoloba* (L) Taub], strip cropping of pearl millet and clusterbean, and four levels of plant populations, viz., 40,000 (low), 88,888 (moderate), 1,33,333 (high) and 2,00,000 (very high) plants ha⁻¹ for each system replicated three times in randomized block design. Row intercropping included one row of pearl millet alternated by one row of clusterbean (1:1). Strip cropping had four rows of pearl millet alternated by four rows of clusterbean (4:4). Desired plant population was achieved by keeping inter and intra row spacing of 100 x 25 cm for low, 75 x 15 cm for moderate, 50 x 15 cm for high and 25 x 20 cm for very high population. At the time of sowing, 15 kg N and 13 kg P ha⁻¹ were applied as basal to all treatments. Additional 15 kg N ha⁻¹ was top dressed 25 days after sowing, to pearl millet only. All crops

were sown with the onset of monsoon by tractor-drawn seed drill and desired plant population was maintained by thinning the plants. For calculating pearl millet grain equivalent, the price of Rs. 2.10 kg⁻¹ for pearl millet and Rs. 5.25 kg⁻¹ for clusterbean was taken. The index of moisture adequacy (Ima) was computed as described by Joshi (1988). Moisture stress was considered to have initiated whenever the value of index of Ima decreased to less than 0.5. The Ima between 0.50-0.26 indicated moderate stress and that below 0.25 indicated severe stress. Water use was computed through water balance which was worked out from moisture observations recorded every alternate day during the season.

Results and Discussion

Seasonal rainfall and moisture-stress

The rainfall received during moisture-sufficiency season was 718 mm in 17 rainy days, while in moisture stress season, it was 182 mm in 15 rainy days. The MI_{ma} in moisture sufficiency season during juvenile, vegetative and reproductive phases was 0.77, 0.85 and 0.78, respectively, indicating no moisture stress in any of the phenophases. In moisture stress season, the crop remained under moisture stress throughout the season except during week 2 and 6 (Fig. 1). The MI_{ma} was 0.64 during juvenile period, 0.41 during vegetative and 0.25 during reproductive phase. The very low value of MI_{ma} during reproductive phase indicated severe moisture stress which led to poor grain yields in moisture stress season.

Grain yield

Row intercropping and strip cropping had 50% less population of pearl millet compared to sole cropping, but produced 16.6 and 35.4% lower only in no moisture stress season, and 35.3 and 37.4% lower in moisture stress season. The differential yield reductions due to plant population change may be attributed to border effects. The system having border rows, therefore, yields generally higher than normal one (Joshi, 1990). Better yields of row intercropping than strip cropping in the present study lends further support to the concept of proportional benefits of number of borders involved in a system, as the former had more border rows than the latter one.

The yield of clusterbean component was influenced by the systems similar to that of pearl millet. However, the difference between two seasons was not much conspicuous. Relatively poor performance of clusterbean in moisture-sufficiency season may be attributed to greater vegetative growth, leading to poor pod setting.

In moisture sufficiency season, the yield of pearl millet was significantly less at low population (40,000 plants ha⁻¹) compared to all other populations (Table 1). Though the yield per plant under this treatment was more than at higher populations, yet it could not fully compensate for the low population effect and thus the soil moisture remained partially unutilized. The moderate and high populations made full use of such resource and gave significantly higher yields compared to low population (Table 1). Though the moisture sufficiency

season had well distributed rain with 17 rainy days, yet at very high population the yield was significantly reduced (1880 kg ha⁻¹) compared to moderate and high population treatments. This is attributable to the intense competition for resources other than moisture. The population response under this season, therefore, had an optima at moderate population and maxima at high population. Both the extremes of low and very high populations, thus gave lower yields. The non-significant interaction between planting systems and population levels indicated independent response of these variables.

Contrary to hyperbolic response to population levels in moisture sufficiency season, leading to a population optima, an inversely linear response was observed in moisture stress season. At low population, the yield was maximum and it decreased with increase in population and was the lowest at very high population (Table 1). The difference between low and moderate populations was non-significant. Reduced yield under higher population was obviously due to severe competition for moisture.

The yield of clusterbean was, however, maximum at very high population in both the seasons. The moisture stress did not influence the yield of clusterbean due to its higher drought tolerance. Even at very high population, the yield response was proportional to the number of plants per unit area.

Water use and water-use-efficiency

The water use (Table 2) was higher (230-265 mm) in moisture-sufficient season

Table 1. Yield (kg ha^{-1}) of component crops as influenced by cropping systems and plant populations (plants ha^{-1})

Treatment	Moisture sufficiency season		moisture stress season	
	Pearl millet	Clusterbean	Pearl millet	Clusterbean
Cropping systems				
Sole pearl millet	2416	-	424	-
Row intercropping (1:1)	2013	583	274	532
Strip cropping (4:4)	1559	466	265	432
Plant population				
Low (40,000)	1604	308	365	274
Moderate (88,888)	2243	331	294	326
High (1,33,333)	2257	354	268	361
Very high (2,00,000)	1880	405	187	424
CD for systems (5%)	121		75	
CD for population (5%)	140		86	

compared to moisture stress season (150-160 mm). The seasonal water use by a crop is governed by leaf area index and duration which is dependent upon the availability of moisture in an arid environment. The

stress-free season in the present study caused longer active leaf growing period (13 days) as compared to that in moisture stress season and was the major factor for higher water use. The sole cropping had significantly

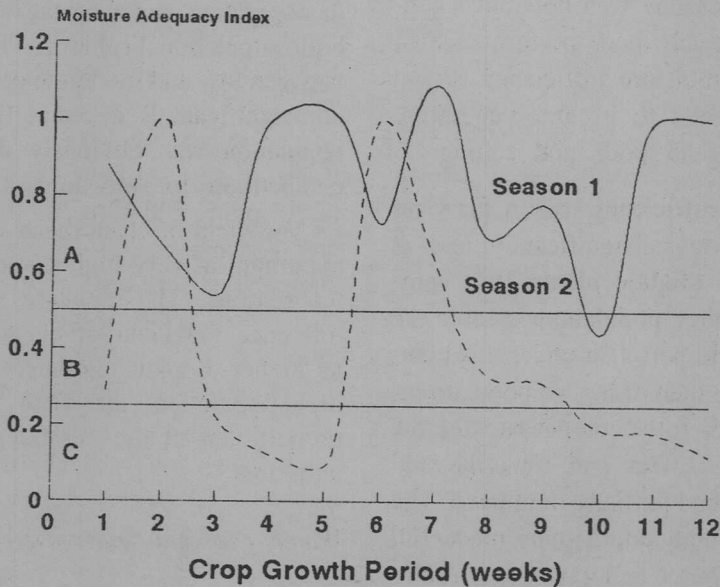


Fig. 1. Crop growth in relation to index of moisture adequacy (A, enough moisture; B, moderate drought; C, severe drought) in moisture sufficient (season 1) and stress (season 2) seasons.

Table 2. Water use (mm) and WUE (kg pearl millet grain equivalent mm^{-1}) in relation to cropping systems and plant population

Treatment	Water use		Water-use-efficiency	
	Moisture sufficiency season	Moisture stress season	Moisture sufficiency season	Moisture stress season
Cropping systems				
Sole pearl millet	246	150	9.82	2.82
Row intercropping (1:1)	260	156	13.14	10.82
Strip cropping (4:4)	251	158	10.80	8.51
Plant population				
Low (40,000)	230	152	10.32	6.90
Moderate (88,888)	245	156	12.53	7.10
High (1,33,333)	250	160	12.56	7.28
Very high (2,00,000)	265	160	10.91	7.80
CD for systems (5%)	12	NS*	1.80	2.80
CD for population (5%)	14	NS	2.07	NS

*NS = Non significant.

lower (246 mm) water use compared to row intercropping (260 mm) and strip cropping (251 mm). Both systems of intercropping created different moisture extraction zones owing to dissimilar root growth habits of pearl millet and clusterbean, such zones being more in row intercropping than in strip cropping, which led to better extraction of soil moisture compared to sole cropping. Increasing the population from low to very high significantly increased the water use from 230 mm to 265 mm. Studies of Azam-Ali (1983) indicated that the leaf area was the main determinant of water loss and had a far greater influence on seasonal water use. Increase in plant population in the present study also increased the leaf area, leading to higher water use.

In moisture stress season, the changes in water use either by cropping system or by levels of plant population were non-

significant (Table 2). This suggests that water use of a system is controlled by availability of moisture, at least to a certain limit.

The WUE in sole cropping was 9.82 and 2.82 kg grain $\text{mm}^{-1} \text{ha}^{-1}$ in moisture sufficiency and stress seasons, respectively (Table 2), and increased significantly under intercropping and strip cropping. Intercropping systems used 8-14 mm more water compared to sole cropping, but significant changes in WUE could be attributed to better resource use. Morris and Garrity (1993) observed that the intercrop environment, composed of two crops of differing stature and growth dynamics, may create characteristics that convey favorable direct effects on transpiration efficiency (i.e. biomass produced per unit water transpired) and, therefore, greater WUE. In the present study, the clusterbean crop, owing to its drought tolerance, resulted in better yields,

more so in moisture stress season and, therefore, contributed more towards higher WUEs of both intercropping systems.

The plant population effects on WUE were significant in moisture-sufficiency season only. Increasing population from low to moderate or high increased the WUE significantly. Further, increase in population to very high lowered the WUE.

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