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Effect of Dryspell Mitigation with Supplemental Irrigation on Yield and Water Use Efficiency of Pearl Millet in Dry Sub-Humid Agroecological Condition of Maiduguri, Nigeria

A.B. Mustapha

Department of Agricultural Technology, Ramat Polytechnic, PMB 1070 Maiduguri, Borno State, Nigeria

Abstract. Five irrigation regimes were laid out in a randomized complete block design at the Teaching and Research Farm of Ramat Polytechnic, Maiduguri located in dry sub-humid zone of Nigeria during the 2009 rainy season to study the effect of supplementary irrigation on the growth and yield of rainfed pearl millet. The soil of the study area was well drained sandy loam with high infiltration rate within the 30cm depth. The CROPWAT version 8.0 of the FAO was used to determine the seasonal pearl millet crop water requirement, effective rainfall and irrigation requirements as 445mm, 248mm and 145mm, respectively. The 84mm of irrigation water applied during booting and grain-filling stages gave the highest yield of 2354.17kg ha^{-1} with 69% yield increase and water use efficiency of 3.58 kg $ha^{-1}mm^{-1}$. It is therefore more suited to the dry sub-humid agroecological conditions of Maiduguri and its adoption can bring substantial yield increase of pearl millet per unit water and land area. It should therefore be adopted to mitigate dry spells in Maiduguri area and other places with similar soil and climatic characteristics to supplement rainfed millet.

Keywords: Agroecological Dry Subhumid Dryspell Mitigation Water use efficiency Pearl millet Supplemental

1. Introduction

In the drier farming regions of the world, mainly with arid and semi-arid environments, crop production is heavily dependent on rainfed practice. Agricultural production is facing increased competition for limited water resources and it is expected to increase with the number of water deficit countries, population pressure and intensification tending towards desertification of most land. The efficiency of utilization of irrigation water is often low and around 50% of the increase in demand for water could be met by increasing the effectiveness of irrigation (Seckler *et al.,* 1998). It is, therefore, important to improve the efficiency of water use and this can be done by approaching the economic maximum of plant material that will ensures high water use efficiency. Water use efficiency nowadays is less improved hence, Mintesinot *et al.;* (2004) viewed that promoting its efficiency demands an urgent attention for improving productivity in dry environment. One of the methods for increasing water use efficiency is the adoption of cultural practices that will enhance production per unit of water. This can be achieved by crop-environment matching and by supplementing the cultural practice with irrigation. Water use efficiency is highly dependent on plant nutrient and, supply therefore any plant input factor that increases economic yield will improve the water use efficiency (Davis, 1994). Moreover, Tesfaye (2004) viewed that water shortage for crop production is not only the result of water scarcity but also of mismatches between the resources availability and demand. Water use efficiency is a major factor for identifying the best irrigation scheduling strategies for supplemental irrigation (Pereira, *et al.*; 2002). Hence, irrigation if well targeted might solve part of food security problem, which is the main goal for improving water use efficiency.

Agriculture in the study area is heavily reliant on rainfall and productivity and production are strongly influenced by climatic and hydrological variability that are reflected as dry spells, droughts and floods. Droughts destroy watersheds, farmlands, and pastures, contributing to land degradation and causing crops to fail and livestock to perish. Dry spells during the rainy season is a common phenomenon in dry sub-humid and semi-arid climates of Nigeria, thus, resulting in low yields or sometimes to complete failure of staple food crops. Bridging the dry spells through supplemental irrigation of rain-fed crops can be an interesting option to increase water productivity at production system level (Oweis and Hachum 2004).

The objective of the study was to determine the water use efficiency of pearl millet at five supplemental irrigation regimes; irrigation at booting stage, irrigation at grain-filling stage, irrigation at booting and grain-filling stages, multiple irrigation and no irrigation (rainfed).

2. Materials and Methods

The experiment was conducted at the Polytechnic Teaching and Research Farm located in the premises of Ramat Polytechnic Maiduguri during 2009 rainfed millet cropping season. The climate was described as dry sub-humid in nature (Ojanuga, 2006) and Hess *et al*., (1996) pointed out that the mean daily temperature ranged between 23.6 and 34.8^{o}C during the cropping season (June to October). The annual average rainfall in the zone ranges between 508 to 762mm (Ishaku and Majid 2010). The soil in the study area was classified as Typic Ustipsamment.

Sowing was done immediately the rain was fully established. Five to ten seeds were planted per hole at a spacing of 75 by 50cm and thinned to two plants per hole a week after germination. Weeding was done manually at two and five weeks after germination and NPK fertilizer was applied at the recommended rate of 80:60:60, nitrogen, phosphorus and potassium respectively (Gwadi *et al.,* 2004).

Data on tiller count were recorded at six weeks after germination when the plants were fully developed. The number of leaves, plant height, girth thickness, number of panicles per square metre, panicle length and panicle thickness were recorded in the twelfth week when the plant was fully matured. Harvesting was done on the 91st day after planting when the seeds could not be crushed between two fingers by cutting the panicles with sharp knife and dried for threshing (Gwadi *et al.,* 2004). The grain yield was weighed and then extrapolated to kg/ha.

The data generated were subjected to analysis of variance (ANOVA) using the F-test as described by Gomez and Gomez (1984) and Akindele (2004). Differences among the treatment means were separated using the Duncan's New Multiple Range Test (DMRT). The statistical software used was STATGRAPHICS Plus Professional Version 5.

3. Results and Discussion

The grain yield as a result of supplementary irrigation in addition to rainfall, total water used and water use efficiency (WUE) are presented in Table 1. Water applied ranged from 573.3 to 821.3 mm. The highest water consumption was recorded in the treatment that had multiple irrigations (MTR) while the lowest was in the rainfed (RFR). BGR produced much more grain yield and gave the highest water use efficiency with addition of only 14.65% more water to the total useful rainfall. This confirms the findings of Seghatoleslami *et. al.,* (2008) and Powell and Fussell (1993) which reported that drought created by low rain, reduced harvest index, thus water stress had more effects on reproductive structures than vegetative one. In another finding Adriana and Cuculeanu (2000) reported that the application of adequate irrigation scheduling reduced yield losses are significantly. Provision of supplemental irrigation of 84mm during booting and grain filling stages (BGR) showed significant effect on the number of panicle, panicle length, chaff weight, grain weight and stover weight indicating that supplemental irrigation is highly beneficial for pearl millet. The improved yield at the as a result of supplemental irrigation during booting and grain filling stages is similar with report by M'mboyi *et al* (2010) which suggested that complete crop failure or reduced yield may result if drought occurs at the flowering or grain filling stages. Pearl millet growth responds to climate (temperature, rainfall, radiation), soil water supply. The treatment had the highest water use efficiency as compared with others. This study points out clearly that if adequate moisture can be supplied during critical stages of growth, the yield reduction will be minimized. The mid season stage was the most sensitive to water stress. The need to supply adequate moisture at this stage is very important. However, it was reported by Yenesew and Tilahun (2009) that the crop water use efficiency was the lowest at optimum irrigation water application and the highest at stress of 75% deficit throughout the growth season. Although they pointed out that at individual farmer's level, maximum yield was obtained when the entire crop water requirement was fulfilled but water use efficiency was very low. Practicing deficit irrigation could increase the irrigated area since that lesser water is always used per unit area thereby resulting in of high water use efficiency.

Multiple irrigation (MTR) and irrigation at grain-filling stages (GFR) have statistically similar yields but multiple irrigation (MTR) had very much lower water use efficiency (WUE) because lesser water was used in the case of GFR. The maximum yield was obtained in Ethiopia when the entire crop water requirement was fulfilled as compared with deficit irrigation. The saved water could be used for irrigating increased area which can compensate for any yield loss.

Table 1: Irrigation water supplies and water use efficiency under different irrigation treatments

Treatment	Grain weight (kg ha^{-1})	Water applied (mm)	WUE
BSR	1864.58^{b}	615.30	3.03
GFR	2083.50^{ab}	615.30	3.39
BGR	2354.17^{a}	657.30	3.58
MTR	2260.42^{ab}	821.30	2.75
RFR	1395.83^{c}	573.30	2.43

Note: Means followed by the same letters are not significantly different

4. Conclusion

Substantial amount of the total rainfall received during the growing season was lost to deep percolation during the 2009 raining season. This was as a result of very high intensity rainfall coupled with high infiltration rate of the soil which was in excess of its field capacity. On the other hand, the rainfall was poorly distributed consequently the risk of dry spells during the growing period of pearl millet was paramount. Supplementary irrigation during booting and grain filling stages recorded the highest yield during the season brought about the significant different in terms of grain yield and water use efficiency. The irrigation depth that produced this yield was much less than the water lost to deep percolation. This confirmed that the yield of pearl millet in dry sub-humid Maiduguri could be related to the number of rain-days of the rainy season rather than reduction in mean rainfall. Supplementary irrigation is a highly efficient practice with great potential for increasing agricultural production and improving livelihoods in the dry sub-humid rainfed areas. Droughts would have a very mild impact if farmers are equipped with the knowledge of supplementary irrigation and especially if combined with soil fertility management. Supplementary irrigation especially during booting and grain filling stages was more promising to be adopted in dry sub-humid agroecological conditions of Maiduguri.

5. References

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