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The influence of soil moisture on maize growth and yield in flood recession farming in the Okavango delta: the case of maize

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ABSTRACT
Flood recession farming (locally known as molapo farming) is a farming system which is based on natural irrigation and fertilization of the floodplain where crops are cultivated on the remaining soil moisture of the receding flood. Maize (*Zea mays*) is the most commonly grown crop in molapo farms and yet the contribution of the moisture regime in meeting the crop's water requirements is poorly understood. In particular the link between residual moisture and moisture supplied by rainfall and its effect on maize growth has not been investigated. This study investigated this aspect at three sites (Tubu, Xobe and Shorobe) located in the Okavango Delta, Botswana where molapo farming is mainly practiced by small-holder farmers. These small-holder farmers are faced with challenges such as high or low floods and fields vulnerable to livestock grazing leading to early harvesting. The study established that main implications for the farming community were that planting too close to the channels may be too wet or waterlogged while moving away from the channel can become too dry leading to poor plant emergence and low yields.

Key words: Flood recession farming, maize growth, maize yield, Okavango delta, soil moisture.

RÉSUMÉ
L'agriculture de récession des inondations (connue sous le nom d'agriculture molapo) est un système agricole qui repose sur l'irrigation naturelle et la fertilisation de la plaine d'inondation où les cultures sont cultivées sur l'humidité résiduelle du sol après l'inondation. Le maïs (*Zea mays*) est la culture la plus couramment cultivée dans les fermes molapo et pourtant la contribution du régime d'humidité requis pour satisfaire les besoins en eau de la récolte est mal comprise. En particulier, le lien entre l'humidité résiduelle et l'humidité fournie par les précipitations et son effet sur la croissance du maïs n'a pas été étudié. La présente étude a étudié cet aspect sur trois sites (Tubu, Xobe et Shorobe) situés dans le delta de l'Okavango, au Botswana, où l'agriculture molapo est principalement pratiquée par les petits exploitants agricoles. Ces petits agriculteurs sont confrontés à des défis tels que des inondations élevées ou faibles et des champs vulnérables au pâturage du bétail, ce qui entraîne une récolte précoce. L'étude a établi que les principales implications pour la communauté agricole étaient que la plantation trop proche des canaux pourrait être trop humide ou gorgée d'eau, alors que la plantation loin des canaux porrait devenir trop sèche conduisant à une mauvaise émergence des plantes et à des rendements faibles.

Mots clés: L'agriculture de récession des inondations, croissance du maïs, rendement du maïs, delta de l'okavango, humidité du sol

BACKGROUND AND RATIONALE

Flood recession farming (locally known as molapo (plural melapo farming) is a farming system which is based on natural irrigation and fertilization of the floodplain where crops are cultivated on the remaining soil moisture of the receding flood (Saarnak, 2003). In Botswana, flood recession farming is practiced along the edges of river channels (Jones and Rashem, 1987) or seasonally flooded depressions (Staring, 1978; Staring *et al.,* 1981) in Ngamiland District on the fringes of the Okavango Delta. It is concentrated in two main areas: the Western delta fringes between Gumare and Nokaneng and the south-eastern part of the delta between Matlapaneng and Shorobe villages. Farmers start planting as early as October when the floods recede. The maximum field size cultivated under

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molapo farming is 2 hectares (Loos, 1986). Maize is the most common cereal crop grown under this farming system, and it is cultivated together with beans, pumpkins, gourds and sweet sorghum.

The soils in these areas are considered to be very fertile because of the organic material deposited by annual floods (Staring *et al.,* 1981). Molapo soils are alluvial deposits with varying sand, silt and clay contents (Bendsen and Meyer, 2002). In the Gumare area soils are often peaty with high organic matter content. Areas suitable for molapo farming include old river beds or other depressions that are flooded or moistened by rising ground water (Gumare area), as described by Jones and Rashem (1987). In Shorobe, basin melapo are used in years of high floods while in years of lower floods farming takes place on river banks (Petermann *et al.*, 1989).

Small scale farmers practicing molapo farming plant crops using traditional methods. These farmers use low input technology such as the cultivation of their fields using animal drawn implements like a mouldboard plough and broadcast seeds of different crops in the same field. Crops are sown in moist soil after soil moisture has been replenished by annual floods. During the growing season crops also benefit from annual rains which mainly fall from November to March. However, the complementary effect of rainfall and residual moisture from floods in achieving good crop growth and yield is not fully understood. Hence this study conducted on-farm trials to investigate the relationship between maize growth, yield and soil moisture content. Although other factors that influence growth of maize such as low soil fertility, high temperatures, weeds and pests were not studied in detail, their importance was recognized in interpreting the research findings. Thus, the study sought to determine the relationship between soil moisture availability and the growth of maize under the molapo farming system. The objectives of the study were to (1) determine the physical and chemical properties of soils of molapo farming fields, (2) determine the effect of rainfall and residual moisture on soil moisture availability during the crop growing season of maize, and (3) determine the growth response of maize based on soil moisture availability at different growth stages.

MATERIALS AND METHODS

Study area. The project was implemented at three sites located in the Okavango Delta (OD) in Ngamiland: Tubu village (19023' S and 22013'E), Shorobe village (19050' S and 23040' E) and Xobe settlement (20026' S and 23042' E). The sites provide different flooding patterns, soil types and local topography. The average local rainfall within the OD is 450 – 550mm per year. From October to March the mean monthly maximum temperature (at Maun) ranges from 31.3 to 34.1^{0}C, while the mean minimum temperature ranges from 17.8 to 19.4^{0}C (Anon, 1984).

Farmer and field selection. This study was conducted as on-farm trials with three sites and was carried out for two seasons. Farmers in each village were asked to volunteertheir molapo fields for the trials. The criteria used for identifying the suitability of the farmer's field were (a) secure fence to keep animals away, (b) easy accessibility of the field and (c) uniformity (topography, soil type) of the land. Investigations on soil moisture and crop growth were done in two cropping seasons (2010-11 and 2011-12).Two fields were selected for soil moisture investigation in each of the three villages for the first season's trials (2010/11). During the second cropping season (2011/12), only one site (Tubu) was used, where three fields were planted.

Experimental Methods. In each field a plot of approximately 25m x 10m was planted with one maize cultivar, namely Kalahari Early Pearl (K.E.P.) using the traditional planting method (broadcasting and ploughing in of seed). For each field a soil pit was dug and soil sampled at 20 cm depth intervals and data on chemical and physical properties obtained. Soil moisture was monitored in all fields. In 2010-11 a gravimetric method was used, while in 2011-12 soil moisture content was measured using a PR2/6 Profile Probe. In each field measurements were done at either two or three sampling points 10m apart on a slope gradient from the lowest to the highest point of the field. Around each sampling point, an area of 6 m x 4 m was marked for data collection on crop growth and yield. Ten plants were randomly selected and tagged two weeks after germination within the 6 m x 4 m area for collecting data on plant height and leaf number still present (only for the second season).

Occurrence of pests, diseases, flower emergence, cob set per plant (before harvesting) and signs of wilting were also recorded. Cob, grain and biomass yield data were collected from the demarcated area. There was no yield obtained in Xobe and Shorobe as crops were damaged by livestock before they reached maturity. No threshed grain yield for Tubu Field 2 was obtained in the first season as the farmer mixed the cobs from sampling area A and B before threshing. In the second cropping season, the cobs were harvested immature (as green mealies) because of floods and farmers' concerns about crop vulnerability to livestock damage.

RESULTS

Table 1 shows the soil physical properties of all seven fields. Plant Available Water (PAW) was low in Xobe soils, moderate in Shorobe and moderate to high in Tubu. Differences could be explained by higher clay content. Tubu soils were peaty with a high organic matter content and consequently low bulk density. In Tubu Fields 1 and 3 soils were peaty in the surface layers, but sandy in lower layers (below about 40 cm). Soil chemical analysis varied between sites and over depth within fields (for brevity data is not shown). In most fields soil nutrient levels declined with increasing soil depth.

Soil moisture content changes closely correlated with rainfall as moisture content increased following periods of high rainfall and then declined with low rainfall in both fields during the first cropping season in Tubu and Shorobe (Figure 1). In Xobe there seemed to be no clear relationship between rainfall and soil moisture as soil moisture content rose even though rainfall was low at that point in the cropping season. The increase in soil moisture content was probably due to a rise in the water level in the Boteti River. During the second season, moisture content in Field 2 and 3 in Tubu correlated with rainfall, while Field 1 did not appear to be substantially affected by rainfall, because the lower sampling points remained above field capacity throughout the growing season (Figure 2). Field 3 was more affected by periods of heavy rains to the extent that the field was flooded leading to early harvesting.

During the first cropping season, maize plants in Tubu grew more vigorously and reached a greater height than plants in Shorobe and Xobe (before crops got destroyed by livestock), probably because of a combination of good soil moisture and fertility of the Tubu fields. In Xobe crops were stunted because of waterlogging. During the second cropping season, stunted growth was observed in Field 1 of Tubu in the lower parts of the field, possibly because of excess moisture from the previous floods which resulted in a raised water table and soil moisture content which exceeded field capacity. Soil moisture content also had an effect on germination, plant stand and flowering, since flowering was delayed in waterlogged areas.

Maize grain yields obtained in the first cropping season at Field 1 in Tubu were very high (an average of 8.11 t/ha) as compared to those reported by other studies. High cob yields were also obtained in the second season in ost plots, except where water logging and/ or poor germination occurred.

Table 1. Average Bulk Density, Field Capacity, Permanent Wilting Point and Plant Available Water for the three study sites

Site	Field	BD (g/cm^3)	FC (mm/m)	PWP (mm/m)	PAW (mm/m)
Xobe	1	1.61	102 3	9	63
Xobe	2	1.68	103 7	0	32
Shorobe	1	1.60	205 3	2	173
Shorobe	2	1.59	168 3	2	136
Tubu	1	1.39	266 8	3	183
Tubu	2	0.70	494	220	274
Tubu	3	1.31	195 7	6	118

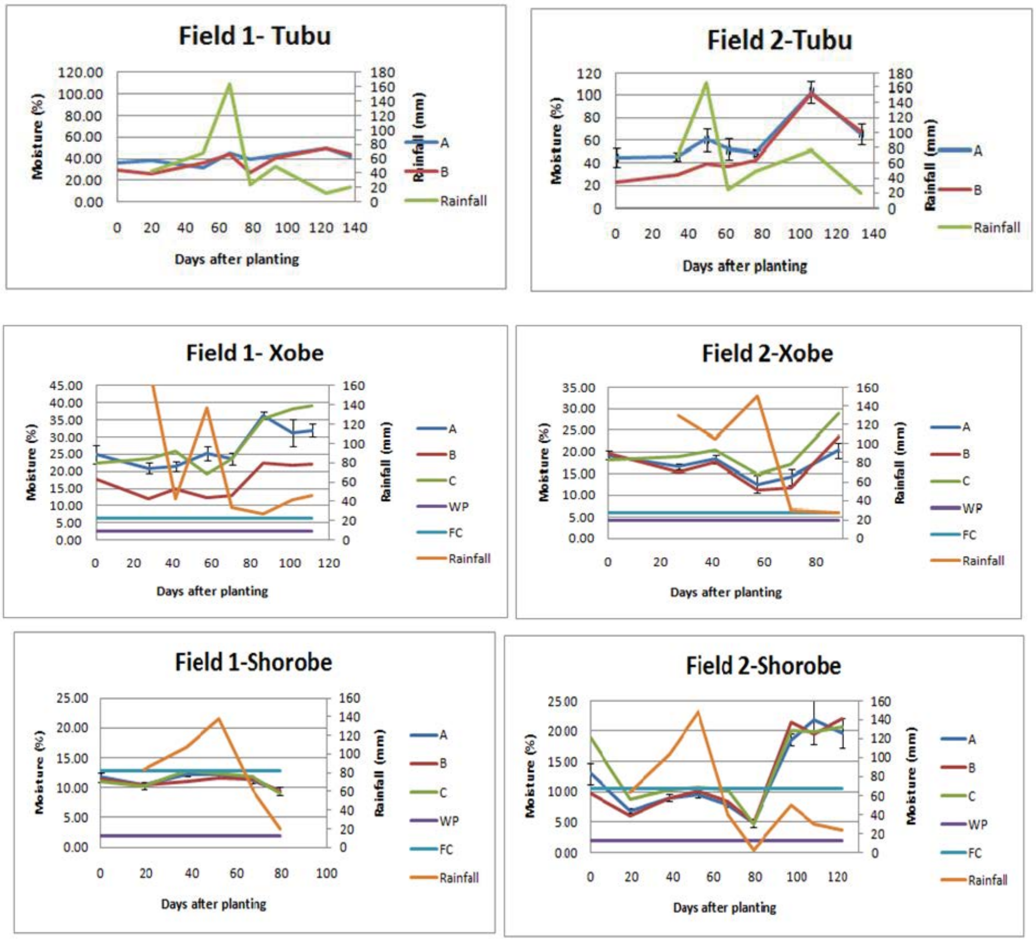

Figure 1. Average soil moisture content observed at different sites in three villages over the growing season of maize during the first cropping season

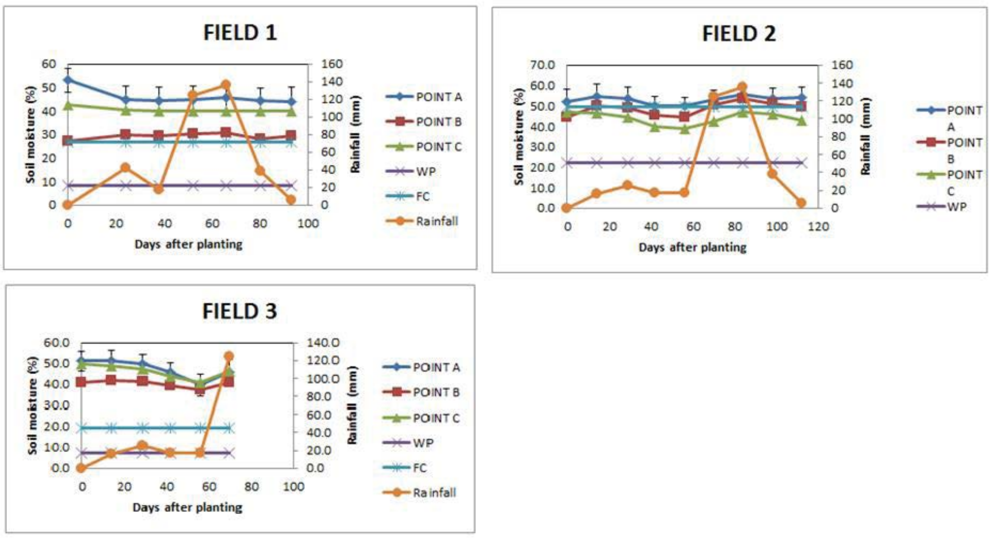

Figure 2. Average soil moisture content (% by volume) at different sampling points within three fields of Tubu during the 2011-12 cropping season

CONCLUSION

The study established that water holding capacity is lower in sandy soils as compared to soils with more clay particles. Soil depth was noted to be a contributing factor in moisture holding capacity. In contrast with what the farmers believe, some deficiency of soil nutrients as found out by Staring (1978) was noted in all the study sites.

The findings of the study confirmed that neither rainfall nor stored moisture alone was adequate for maize production. It can be concluded that moisture levels can be too high or too low for optimal growth in molapo fields. It was established that excess moisture led to poor plant stand, while lower moisture content in the upper part of the field led to delayed germination. The study also found out that waterlogging, as a result of a raised water table led to delayed flowering. According to the findings of the study, moisture stress can be a problem in the upper part of the field in years of low floods and erratic rainfalls. It was established that very high crop yields can be obtained, with evidence that yields from the best sampling areas were even greater than those previously reported. However yields vary over short distances, therefore, distance from the flood channel is critical.

RECOMMENDATIONS

It was observed in this study that waterlogging was aproblem in the lower parts of the field since it resulted in stunted crop growth. It is recommended that planting in the lower parts of the field should not be done in years of heavy rainfall to avoid poor germination and stunted growth due to waterlogging. There is a need to plant neither too low in the field, nor too high up the slope. As a result there is high potential yield from a narrow strip close to the channel. Therefore, farmers should be sensitised onthe weather forecast of the season. According to the results of this study, it is evident that molapo fields have the potential to produce higher yields than rainfed farming, therefore farmers need to be trained on improved technologies of planting such as considering plant density (row planting) for improved yields which can improve food security in the country.

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STATEMENT OF NO -CONFLICT OF INTEREST

We the authors of this paper declare that there are no conflicting interests in this publication.

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