AGRICULTURAL PRODUCTIVITY OPTIMIZATION IN WATER SCARCE SEMI-ARID REGION OF ETHIOPIA

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Abstract

Water scarcity is one of the major constraints for development of agriculture in arid and semiarid areas of Ethiopia. Ethiopia has a high population density (85 million) growing at a fast rate of 3.2%. Even under the best rainfed season, there will be a cereal deficit of up to 6.5 million tons per year. Hence, it is imperative to identify and implement technologically feasible, socially, economically and environmentally acceptable irrigation water and crop management practices for optimum agricultural production and productivity under drought and deficit water supply conditions. To this end, a PhD research focusing on enhancing Tef production was initiated in 2009 and field and experimental investigations are on-going. The implications on yield of land preparation, seeding rate (25, 10 and 5 Kg per ha) are being studied in conjunction with water deficit irrigation (75%, 50% and 25% of optimum water requirement). FAO AquaCrop model is being employed to simulate yield response to water and to explore alternative water management strategies in Tef production. Tef (Eragrostis Tef) is overwhelmingly important and critical for the national food security - it is a major stable food crop. Preliminary results have indicated that properly preparing the land thereby impounding the limited water supply and reducing the washing of fertilizers could increase the yield from the current 0.9 ton/ha to 2.5 ton/ha even when only 75% of the water demand of Tef is supplied. Furthermore, reducing the seeding rate from 25 to 10 kg/ha could minimize lodging problems and potential raise the yield to 5 tons/ha.

Key words: Irrigation water management; Tef; Ethiopia; Food security; Water Deficit

Résumé et conclusions

La pénurie d'eau est l'une des contraintes majeures pour le développement de l'agriculture dans les zones arides et semi-arides de l'Ethiopie. L'Éthiopie est un pays avec une forte densité de population estimée à environ 85 millions de dollars qui est en pleine croissance à un taux annuel de 3,21%. Le taux de croissance de la population est supérieure à la croissance de la production alimentaire. Même dans le scénario de saison des pluies mieux tomber, l'agriculture pluviale seul pouvait pas suffisamment face à la demande alimentaire de la population - le pays pourrait encore faire face déficit céréalier de jusqu'à 6,5 millions de tonnes par an. Par conséquent, il est impératif d'identifier et de mettre en œuvre innovation et d'adaptation techniquement possible, socialement, économiquement et écologiquement acceptables approches de gestion de l'eau et les pratiques de production agricole et une productivité optimales en vertu de la sécheresse et des conditions de déficit d'approvisionnement en eau. Pour étudier ce fait très en profondeur, une recherche de doctorat a été lancé en 2009 et sur le terrain et une étude expérimentale, à cette fin sont en cours. Cette recherche doctorale se concentre principalement sur l'amélioration de la production de tef. Au niveau expérimental, les conséquences sur le rendement de la préparation des terres, le taux de semis (25, 10 et 5 kg de Tef ha) ont été et sont actuellement étudiées en liaison avec l'irrigation déficitaire de l'eau (75%, 50% et 25% de l'eau optimale obligation). FAO AquaCrop modèle est utilisé pour simuler la réaction des rendements à l'eau et à explorer d'autres stratégies de gestion de l'eau dans la production de TEF. Tef (Eragrostis tef) est extrêmement importante et essentielle pour la sécurité alimentaire nationale. TEF est une culture vivrière importante stable. Les gens le préfèrent à toutes les autres céréales et de manger deux ou trois fois chaque jour. Les résultats préliminaires ont indiqué que bien préparer la terre et mise en fourrière du manque d'eau ainsi que la réduction du lavage des engrais pourrait entraîner une augmentation de rendement de 0,9 tonnes / ha (sous champ agriculteurs pluviales ») à 2,5 tonnes/ha. Ce rendement de 2,5 tonnes/ha pourraient être maintenus, même à 75% de l'approvisionnement en eau optimale, si l'état de manque d'eau durant la floraison est évité. En outre, un taux de semis de 10 kg / ha a été jugée optimale - cela minimise le logement, la contrainte majeure pour la production de TEF. Si toutes ces pratiques de gestion en eau des cultures mises en œuvre, le rendement en grain Tef peut être poussé à 5 tonnes /ha

1. INTRODUCTION

1.1 Back ground and Rationale

Of all the gifts of nature, none is more essential to living being than water. Arid and semiarid regions of the world such as Ethiopia, mostly faces with inadequate, irregular and erratic nature of rainfall. In addition with recurrent drought lack of efficient use of scarcely available water amplified the impact of water scarcity in agricultural production and productivity. The reduction of Agricultural production results from a combination of many factors, such as crop management, crop genetics and biotic stress. Achieving more agricultural production to meet the growing demand for food, feed and fuel and fiber for the rapidly increasing population is a continuing and ever increasing challenge.

To sustain the rapidly growing Ethiopians populations, agricultural production will need to increase, yet the proportion of fresh water currently available for agriculture is decreasing as the allocation of water to different uses increases (IWMI 2000). Hence sustainable methods to increase crop water productivity and agricultural productions are gaining importance in Arid and semi arid region of Ethiopia (Engida, 2000). Traditionally agricultural research has focused primarily on maximizing total production. Recently focus has shifted to the limiting factors in production, notably the availability of either water or land, directing all the efforts to improve water use and management in agriculture is now a must. Within the context, the water management "how much water at what time" is influencing and examining the best management practice in order to optimize agricultural water productivity, where water is the limiting factor in agricultural production (Oweis and Hachum, 2006; Raes etal., 2006a), This was presumably due to the deference in water requirement of the crop under different growth stages (yenesew et al., 2009; Tefera etal., 2000b).

The target crop Tef *(Eragrostis Tef)* has been grown as a rescue crop in case of failure of other cereal in areas where the nature of rain fall is very seasonal, erratic and low (Ketema 1997). Despite of this fact, the main advantage of Tef is that both the grain and the straw fetch a relatively higher price in the market in comparison to other cereal crops. In Ethiopia Tef is grown mostly for human consumption and is the major staple cereal and food crop of Ethiopians, more over the crop is well adapted to the changing environments where farmers may face a complete crop failure due to moisture stress; Tef is the crop of choice to get some harvest. Its straw is used as livestock feed. The area of Tef cultivation is increasing and it currently occupies the largest hectare among cereals in Ethiopia. Tef grain fetches a high market price; it also serves as an important cash crop. Tef has recently begun to be exported, thus contributing to foreign exchange generation for the country.

This paper will examine in detail the innovative alternatives of different water management and agronomic practices in closing the gap in agricultural production and aims to be a contribution of the broad scientific research on sustainable water use in arid and semi-arid regions. The main focus is on optimizing agricultural production and productivity in water scarce region by using innovative water management practices. In arid and semi arid environments the irregular and unpredictable character of the rainfall determines the agricultural production. Many families are directly related with this UN erratic nature of rainfall for their survival. In the central rift valley of Ethiopia one of the main obstacles to developing sustainable agriculture is seasonal water shortage. Given that Tef is a staple food crop, its production is critical for the national food security. So increasing the efficiency of both rain water and irrigation water use would improve the area food production and in turn improve the country's food security.

2. MATERIAL AND METHODS

2.1. Description of the Study Site

Melkassa is one of the 12 federal research centres in Ethiopia and focuses on dryland agriculture towards sustainability aspects of crop production and the participation of stakeholders. Melkassa Agricultural Research Centre (MARC) is situated in the semiarid region of Ethiopia as 'hot to warm semiarid lakes and Rift Valley'. Mamo 2006 divided the Rift Valley in to four agro climatic depending on the rainfall amount and risk assessment in crop production. Melkassa is categorized under 3 zones characterized by an annual rainfall ranging between 600-800 mm(Table 1).

Table 1 Aridity Index (AI) at semiarid region of Ethiopia (MARC) (Hensley etal., 2000)

	Melkassa /Ethiopia		
Month	Rainfall(mm)	ETO(mm)	AI
January	14	167	0.08
February	26	167	0.16
March	51	189	0.27
April	52	180	0.29
May	52	186	0.28
June	68	177	0.38
July	186	149	1.25
August	181	140	1.30
September	82	135	0.61
October	42	164	0.25

November	8	171	0.04
December	11	171	0.06
Total	772	1994	0.39

2.2. Climate Data Collection and Analysis

Melkassa is classified in the semiarid agro ecological zone of Ethiopia (Ministry of Agriculture (MOA), 2000; Bennie, 2001). The monthly rainfall distribution is a bimodal type of rainfall distribution. The main rainy season is during the months of June to September, during which 68% of the annual rainfall occurs (Table 2). The main dry season extends from October to February, being longer and drier in the north. The highest evaporative demand occurs during the months of March, April and May. During these months, the mean maximum temperature (T max) is around 30^0C while the mean relative humidity (RHm) drops to 51%. During the main crop growing season of June to September conditions are more favourable with Tmax and RHm approximately 27^0C and 64% respectively.

The agro ecological zones classification of Ethiopia (Ministry of Agriculture (MOA), 2000; Engida 2000), mentions Melkassa is classified under areas with two growing seasons. Two growing seasons of 50 and 100 days length for the 1^{st} and 2^{nd} seasons, respectively, and has an annual rainfall and potential evapotrinspiration of about 772 mm and 1994 mm, respectively. The AI of 0.39 identifies this as a semiarid area.

Table 2 Mean Monthly Climatic data of Melkassa Meterological Station (1977-2003) (Welderufael, W.A., 2006).

Month	Rainfall (mm)	MinT (^{0}C)	MaxT (^{0}C)	RH (%)	S shine (Hr)	WindSp (k/hr)	ETO (mm)	A.I
January	14	12	28	52	8.9	11	167	0.08
February	26	13	29	50	8.7	12	167	0.16
March	51	15	30	52	8.3	11	189	0.27
April	52	15	30	51	8.3	10	180	0.29
May	52	16	31	51	8.9	10	186	0.08
June	68	16	30	53	8.4	12	177	0.38
July	186	16	27	67	7.0	12	149	1.25
August	181	15	26	69	7.2	10	140	1.29
September	82	14	27	65	7.3	6	135	0.61
October	42	12	29	50	8.6	8	164	0.26
November	8	11	28	46	9.7	11	171	0.05
December	11	11	28	49	9.5	11	171	0.06
Total	772						1994	
Mean		14	29	55	8.4	10		0.39

2.3. The Soil

The soil of the study area is Loam soil with 41% silt, 37% sand and 22% clay content, and a pH of 6.5. The ecotope name is therefore Melkassa Calcic Fluvic Regosol. This Soil covers about 10% of Ethiopia and about 16% of the rift valley (Itanna, 2005). The Important characteristics of the Melkassa Soil are a favourable clay loam texture of the fine earth throughout the profile, with high silt content with effective depth of

100-150 cm. The top soil is strongly crusting. The water holding capacity of such soils within the root zone is considered to be high.

3. RESULT AND DISCUSSION

3.1. Tef Production in Ethiopia

The target crop Tef (Eragrostis Tef) is one of the most important cereal crops in Ethiopia and Ethiopia is the centre of origin and diversity. More than half of the area under cereal is for Tef production (Habtegebrial et al., 2007). Tef is a small grained (0.2 - 0.3 mg per kernel) and C4 cereal plant of medium stature and short growth duration. Most probably Ethiopia is the only country to grow Tef as human consumption. In Ethiopia 66 % of the population relies on Tef for nutrient supply. Currently in the US Tef grain uses as a health food. South Africa, Europe, Yemen, India know it as a fodder genus/species.

Tef is grown primary as a cereal crop in Ethiopia where it is ground in to flour, fermented for three days then made in to Injera . Injera is a major food staple, and provides approximately two-thirds of the diet in Ethiopia. It is also eaten as porridge and used as an ingredient of home brewed alcoholic drinks with high protein, mineral and vitamin content (more than maize, sorghum and wheat). Tef is so overwhelmingly important in Ethiopia that its absence elsewhere is a mystery. Enhanced and secured Tef production using innovative and improved irrigation water Management practice by varying the level of water at different growth stage of Tef production is crucial and new practice for increasing the production of Tef in water scarce area of Ethiopia.

3.2. Importance of Tef in small Holder Farming Systems.

In Ethiopia, Tef is grown mostly for human consumption. Tef has its own agronomic and food quality that make it the most important crop to the farm house hold compared to other crop enterprises. Tef is the most preferred crop than other cereal because of best Enjera quality, straw quality for livestock feed, seed storability, drought resistance and ability to provide more satisfaction from a small weight of the grain (table 3).

Tef is a type of crop that has been cultivated for a long period of time in the country, and is able to provide reliable yield under unreliable agro climatic condition. Furthermore Tef is adapted to a broader range agro climatic environments, it can grow in altitude ranging from sea level to 2800 m.a.s.l. under different moisture, soil, temperature, and rainfall regime. It has easy of storage and tolerance to weevils. The straw is preferred to any other cereal straw and can fetch additional price from the high demand and high value grain, farmers can earn more from growing other cereals. It is the first cereal in area coverage, demand and market value in Ethiopia. Tef contains high amount of mineral than barely, grain sorghum and wheat. As compared to other cereals, the largest cultivated land area is covered by Tef. Furthermore the area of Tef production is increasing from time to time as the demand for Tef in different regions of the country boosts (Hailu and Seyfu, 2000). Tef is nearly gluten free, and is gaining popularity in the whole food and health food insecurity in the U.S. as an alternative grain for persons with gluten sensitivity.

Table 3. Comparison of Tef with three main cereals produced in the Central Rift Valley of Ethiopia. (Hailu et al., 2001)

	Crop			
Criterion	Tef	Millet	Maize	Barely
Yield	3.46	4.5	3.37	3.94
Food Quality	4.89	3.16	3.39	3.38
Drought tolerance	3.99	3.16	3.32	3.70
Labour requirement	3.03	2.32	3.73	3.55
Performance on poor soil	3.54	3.25	2.59	3.55
Maturity length	3.18	2.38	4.21	4.87
Contribution of soil fertility	2.56	2.27	3.64	3.37
Tillage requirement	2.81	2.49	3.87	2.96
Residue important	4.96	3.60	3.23	3.67
Storability	4.36	4.89	2.52	2.59
Satisfaction	4.11	4.54	3.52	2.86
Garand mean	3.72	3.34	3.34	3.53
Over all rank	1	4	3	2

3.3. Profitability of Tef Production.

Tef has higher market price than those for the grain and the straw of other cereals, Tef is raised to be the most favourite cash crop, even though many families only produce this low risk crop only for their house hold consumption (Hailu etal 2001).

The profitability of Tef production differs in different regions and time with high rate. The magnitude of its profit and rank among crop enterprises depends on

whether each input used in grain and straw yields has a market value. Comparing the price of 1Quintal Tef at the moment and before 10 years, the price at this time is more than fivefold of the price before ten years; Before 10 years the price of 1Quintal of Tef with a high quality Tef costs 200 ETB, currently the price of the same quality Tef of 1 Quintal is 1000 ETB. The increase in price shows the demand of the population for Tef is increased through time.

3.4. Main challenges of Tef production: Its Management alternative

There are various challenges encountered in Tef production which are related to the Tef cultivar itself and additional inputs which contribute to the production of Tef are lack of improved variety, sawing method and seeding rate, lack of input like fertilizer, insecticide and pesticide. There are many more constraints starting from availability of water and quality of soil. Especially in central rift valley of Ethiopia and the low lands the soil has a characteristic effect of salt. Salt affected soils are serious threats to crop production in the arid and semiarid tracts of the Ethiopia (Hailay etal., 2000). This is because under the prevailing situation of the country, there is a tendency to introduce and implement large scale irrigation agriculture in order to meet the demand of the ever increasing human population by optimizing agricultural productivity. In the absence of efficient ways of irrigated water management, salt build up is an inevitable problem. The degree of the setback becomes worsen as the amount of evaporation is very high in the area. As the availability of irrigation water in arid and semiarid area of the country is very law.

The water management "how much water at what time" is influencing and examining the best management practice in order to optimize agricultural water productivity (Oweis and Hachum, 2003;Raes etal.,2006a) , This was presumably due to the deference in water requirement of the crop under different growth

stages(yenesew et al., 2009;Tefera etal.,2000b).This is therefore, Under condition of water scarcity, the limited available water should be used as efficient and productive as possible.

CONCLUSION

Among other cereals grown in the central rift valley of Ethiopia, Tef plays a central role in the livelihood of Ethiopian smallholder farming systems. Farmers use Tef as a rescue crop and grow at the time where the condition is unfavourable for plant production. Tef is a reliable cereal for unreliable climate. Its straw, left are the most preferred for animal feed and also used as a plastering for various traditional structures. For farmers, it earns more value than any other cereals cultivated in Ethiopia. Despite this and several of its advantages over the other crops grown in the country, other than scarcity of water lack of improved cultivar (seed), poor soil fertility, lack of fertilizer remain to be the major constraint impeding the productivity of Tef.

Irrigating Tef(Eragrosstic Tef) is one way of Increasing Tef production. Since the crop is the main daily staple food for over 50 million Ethiopians. Thus, improvement on Tef production and yield stability is vital to the promotion of food security in Ethiopia. The research area (Melkassa Agricultural Research Centre) is found in Semi- arid areas of Ethiopia; mostly this area faces a water deficit and irrigating Tef not fulfilling the full crop water requirement by applying water only in the growth stage sensitive for water stress is one way of managing the scarcely available water.

Over all a strategy of stressing Tef at the beginning and end of the growth season, and using the water to irrigate a greater area, result in a higher aggregate

production than providing optimum irrigation throughout the season for a small area.

In addition decreasing planting rate is one of the agronomic practices in increasing Tef production , as the number of seeds decrease in one sq metres of the area not only save the seed of Tef but also make the tillering potential of Tef high this in turn directly related to increasing the production of Tef.

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Acknowledgements

The Author expresses her sincere appreciation to the Netherlands organization for International Cooperation in Higher Education (NUFFIC) for supporting the research financially.

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