Evaluation of Deep Bed Farming System in Malawi

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Abstract

In Malawi, the traditional ridge and furrow system practiced by the majority of the population is characterized by crops being grown annually on raised ridges through the continuous hoeing and tillage of the land. This system is widely regarded as being both labour intensive and environmentally destructive, and evidence suggests that it leads to significant problems and consequently a decline in crop yields over time. Though farmers have increasingly demanded and adopted the Deep Bed method of farming due to its apparent superior performance even under stressful agronomic conditions such as dry spells, the technology is yet to be approved for farmers use in Malawi. An experiment was therefore, conducted to evaluate different cropping systems under deep bed farming system in comparison with the traditional hand hoe tillage practice. The experiment was conducted both under on-station at Bolero, Bvumbwe, Chitala, Chitedze and Zombwe research stations and on-farm conditions in some Experimental Planning Areas (EPAs) in Balaka, Kasungu and Salima districts. The design of the study was randomized complete block design (RCBD) arranged in a 2X4 factorial fashion with cropping systems as main plot and tillage as sub-plots. Cropping systems included sole maize cropping and maize-legume intercrop while tillage treatments included conventional hand hoe tillage without box ridges (CT), conventional hand hoe tillage with box ridges (CT-B), deep bed (DB) and Pit planting (PT). The study revealed that deep bed tillage system increased maize grain and biomass yield in all the agroecologies. Similar to crop yield, Deep bed together with pit planting and conventional tillage with box ridges also increased soil moisture content. In general, Deep bed farming can be viewed as a new good technology that may be promoted among farmers in Malawi as it increases both maize and biomass yields. The increased biomass production may lead to increased soil organic matter in the long run as the crop residues are retained on the soil surface.

Key words: *Deep bed; Conventional tillage; Agro-ecology; Crop yield; Soil moisture; Smallholder farmers*

1.0. Introduction

In Malawi, the traditional ridge and furrow system practised by the majority of the population is characterised by crops being grown annually on raised seedbeds through the continuous hoeing and tillage of the land. This system is widely regarded as being both labour intensive and environmentally destructive, and evidence suggests that it leads to significant problems of soil compaction and erosion, the loss of organic matter, a reduction in water infiltration, and consequently a decline in crop yields over time (especially in the absence of chemical inputs)

(Ngwira et al. 2013). Traditional tillage practices coupled with crop residue removal (Figure 1) from fields hasten soil organic carbon decline in agricultural lands (Huang et al. 2015). Conservation agriculture (CA) is one of the strategies that may be employed to minimise soil degradation and improve crop production (Wall 2007; Huang et al. 2015). Conservation agriculture is characterised by three principles namely: continuous minimum mechanical soil disturbance, permanent organic soil cover, and diversification of crop species grown in sequence and/or associations. However, predominance of soil hard pans due to prolonged use of the hand hoe in the predominantly smallholder agricultural systems, the *No Till* pillar contributes to failure of CA to effectively control erosion, increase water infiltration and create conducive soil condition for proper root development especially in the early years of implementation. The soil hard pan is prevalent in the country and contributes to reduced yield. In the late 1990s, FAO commissioned a countrywide study to determine the prevalence of the soil hoe pan. The results showed prevalence of the hoe pan in all the 8 ADDs across the country due to continuous use of hand hoe for cultivation. The hoe pan was found to contribute to loss of soil and water through erosion and reduced maize yield of between 0.6 - 0.8 tons/ha (FAO, 1999). Every year the country loses 29 tones/ha/year through erosion (FAO, 2016).

Figure 1: Traditional Tillage System

Upon realising the hard pan problems associated with hoe ridging and initial soil compaction under CA, Tiyeni Organisation introduced the **deep bed farming** (DBF) system. Deep bed farming promotes deep tillage to break down the hoe hard pan ***in the first year of cultivation only*** to achieve increased soil infiltration, proper root development and reduce water loss. In this method of farming, after breaking the hard pan, flat-topped planting beds are made along contour line, with closed-end furrows that harvest water. Technically, the contour-aligned planting beds reduce the field slope to zero thereby stop erosion, enhance water infiltration and percolation and presumably recharge of aquifers. On the other hand, the Deep Bed farming effectively more than doubles the crop yield in the first year of implementation (Figures 2 & 3). The adaptation of CA by deep tillage and creation of planting beds at zero slope is an important innovation that makes CA work in this part of Africa. It is important to realise that while CA works well in the Americas and other regions, studies have shown that its implementation in Africa, particularly the semi-arid regions, presents challenges different from where CA originated (Giller et al. 2009). Studies have shown that deep tillage and mulch management to improve water infiltration and reduce water loss from the soil surface in crop fields have potential to substantially improve crop yields and soil conditions in the semi-arid tropics (Hussain et al. 1999; Findeling et al. 2003; Tarkalson et al. 2006; Adekalu et al. 2007). The Deep Bed farming method requires that soil be tilled up to 30cm depth in the first year after which, no compaction of beds and no till for more than 5 years of growing crops.

Figure 2: Deed Bed Farming system showing water being held within the field

Figure 3: Maize-bean intercrop field under Deep Bed Farming

The Deep Bed method of farming has been tested and implemented for the past 10 years within 45km radius of Mzuzu and other extension planning areas (EPAs) in Mzuzu ADD. However, from 2016, more than 3,500 smallholder farmers practice the technology in all the three regions of the country, most of them without project support. Government extension workers (AEDOs) and farmers learn and copy from practicing farmers and adopt the practice after observing that the Deep Bed farming has led to increased crop yields, controlled soil erosion and harvested water, improved water infiltration and moisture retention. In a recent study on adoption of the Deep Bed method, over 87% of farmers practicing the method were motivated by increased crop yields, with over 90% of them experiencing doubled yields (Albert, 2017, unpublished).

Though farmers have increasingly demanded and adopted the Deep Bed method of farming due to its apparent superior performance even under stressful agronomic conditions such as dry spells, the technology is yet to be approved for farmers use in Malawi. It is therefore crucial to conduct the research work to collect adequate scientific information to confirm the applicability of the Deep Bed farming system to Malawi's conditions. An experiment was therefore, conducted to evaluate different cropping systems under deep bed farming technique in comparison with the traditional hand hoe tillage practice.

2.0. Materials and Methods

Sites Description

The trial was conducted in the 2019-2020 cropping season both under on-station and on-farm conditions. The trial was strategically located to cover all the three agro-ecologies in Malawi namely the low, mid and high altitude agro-ecologies. For the on station sites were Chitala and Bolero located in the Low altitude agroecological zone, Chitedze and Zombwe in the Mid agroecological zone and Bvumbwe in the high altitude agroecological zone. For on farm conditions, the trials were located in Bazale extension planning area (EPA) in Balaka district and Chinguluwe EPA in Salima for the low altitude agroecology while it was located in Mthunthama EPA in Kasungu district and Madisi EPA in Dowa district for the mid altitude agroecology. There was no site under on farm conditions for the high altitude agroecology. The trial at Madisi was either mismanaged or abandoned by the hosting farmers as such this report presents results from all other sites except from Madisi. The map in figure 1 summaries the trial locations.

Rainfall

Daily rainfall was recorded in each site with a rain gauge. During the experimental period (October 2019 to May 2020), average annual rainfall for on station sites was 1241, 841, 1183, 808, 876, and mm for Bvumbwe, Chitedze, Chitala or Chinguluwe, Bolero, Zombwe research stations, respectively (Figures 2-6). The annual rainfall for Mtunthama and Bazale were 580 and 771 mm, respectively (figure 6)

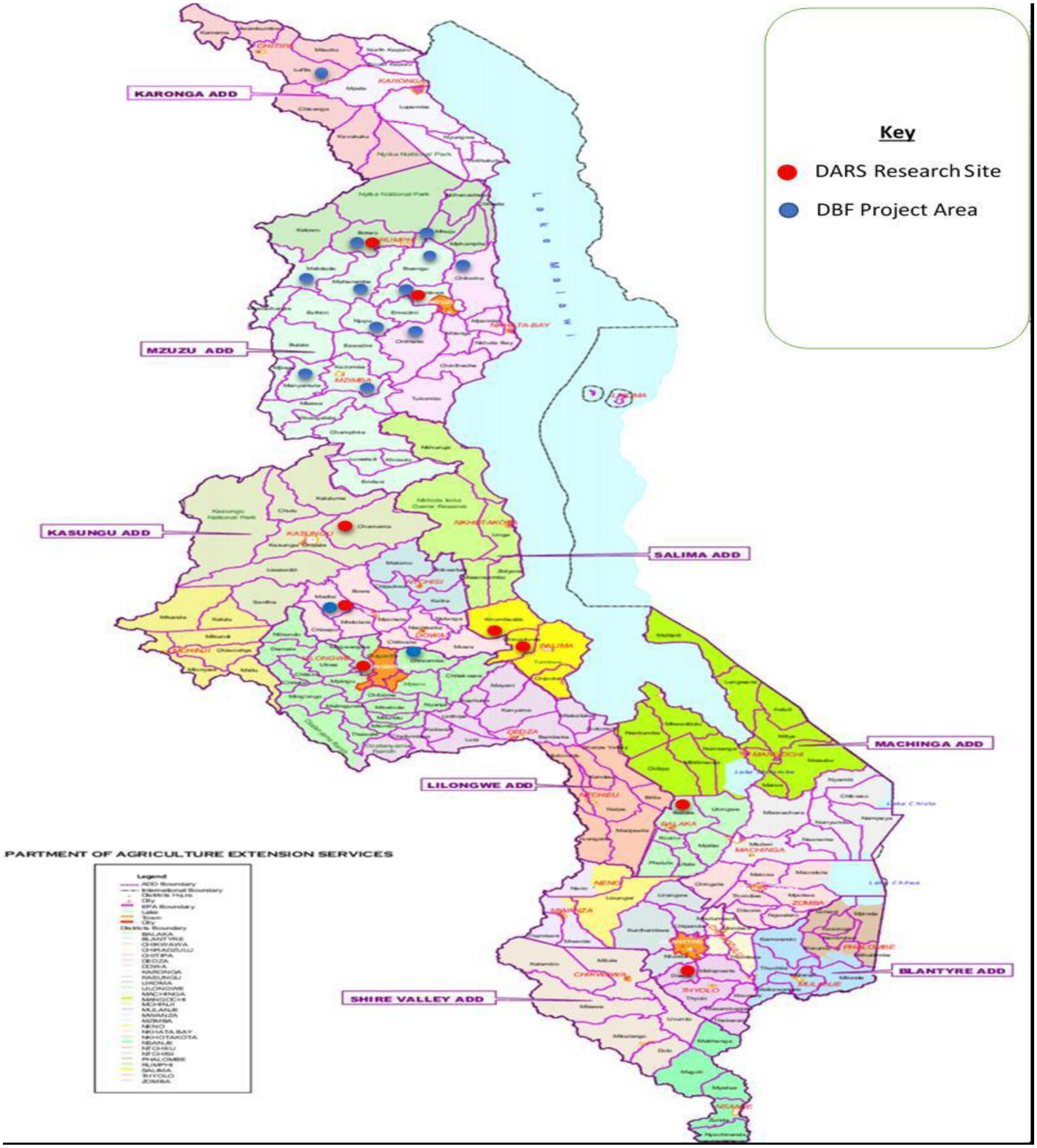

Figure 1. Map showing the trial sites

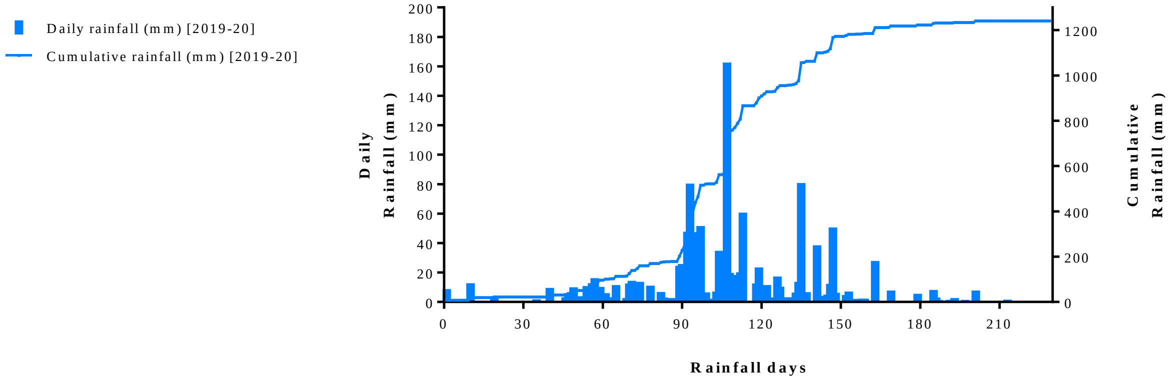

Figure 2. Daily and cumulative rainfall for Bvumbwe research station during 2019/2020 cropping seasons

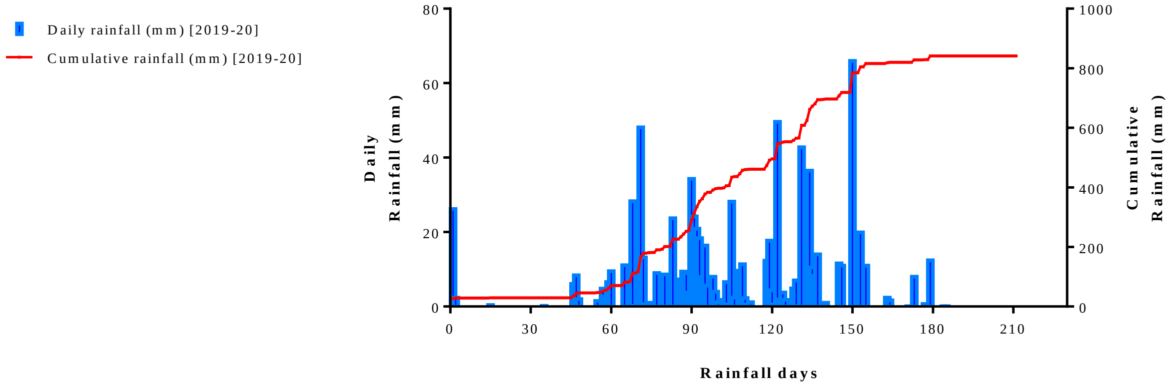

Figure 3. Daily and cumulative rainfall for Chitedze research station during 2019/2020 cropping seasons

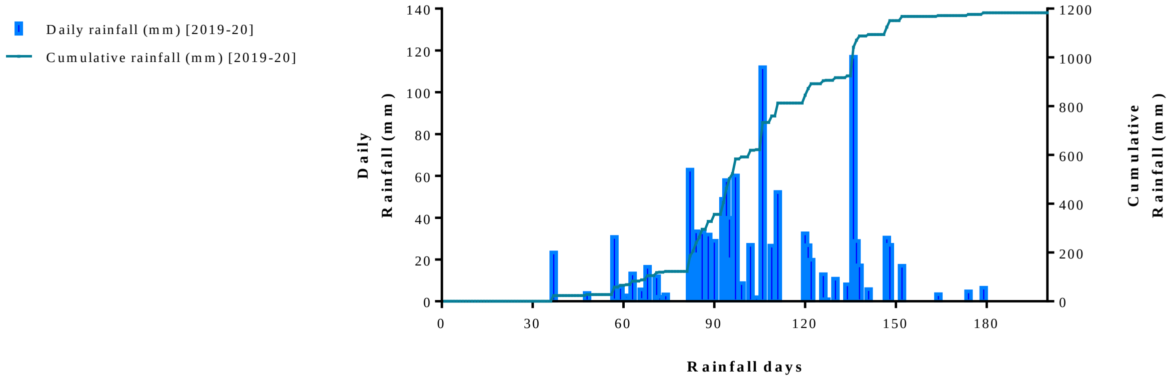

Figure 4. Daily and cumulative rainfall for Chitala research station during 2019/2020 cropping seasons

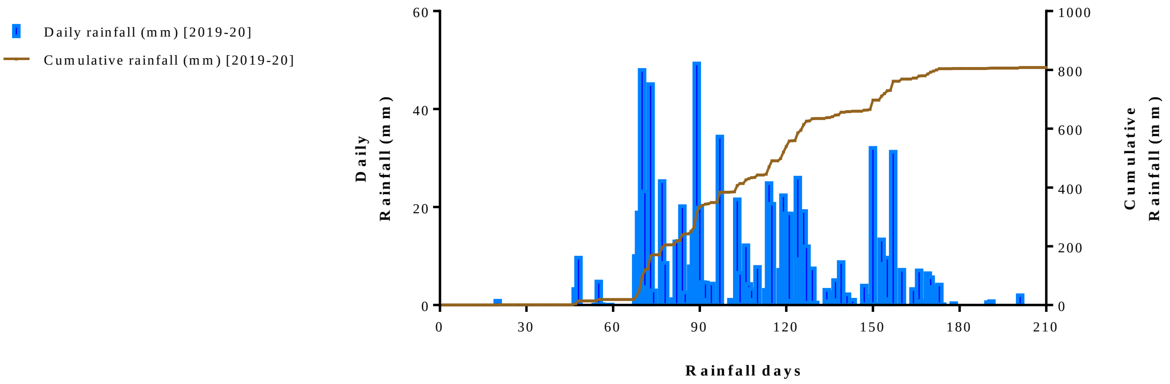

Figure 5. Daily and cumulative rainfall for Bolero research station during 2019/2020 cropping seasons

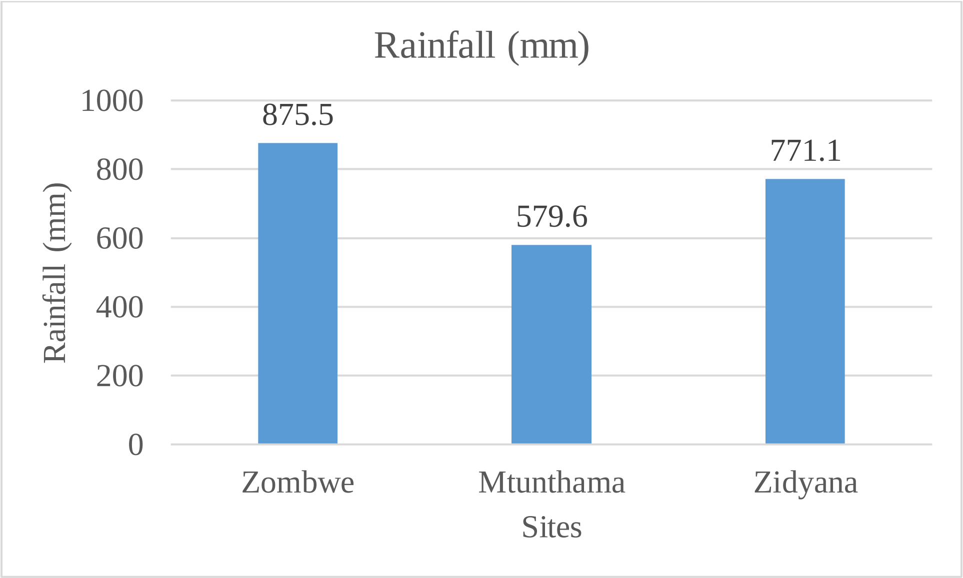

Figure 6. Annual rainfall for Zombwe, Mtunthama and Zidyana during 2019/2020 cropping seasons

Experimental Design

The study was conducted on-farm in some EPAs in the four districts, with six (6) farmers per EPA, each farmer having eight plots making a total of twenty four (24) farmers hosting on farm trials. The design of the study was randomized complete block design (RCBD) arranged in a 2x4 factorial arrangement with cropping systems as main treatment and tillage as sub-treatments. For on station trials, the study used three replications while each farmer acted as a replicate on-farm. Cropping systems included sole maize cropping and maize-legume intercrop while tillage treatments included conventional hand hoe tillage without box ridges (CT), conventional hand hoe tillage with box ridges (CT-B), deep bed (DB) and Pit planting (PT).

Trial management

On-farm sites were managed by farmers in target communities with support from extension officers and research technicians providing recommendations on management of the plots. Research scientists and technicians provided scientific oversight. Seedco long duration hybrid maize, SC719 was planted at all sites. Sudan 1 cowpea variety was used at all the sites except at Bvumbwe where NUA 45 common bean variety was used. The choice of varieties by the farmers was largely based on their decision to avoid exposing the crops to terminal drought. In all deep bed and pit planting plots, residues were laid as surface mulch.

Soil moisture

Soil moisture was determined in the field using the Time domain reflectometry (TDR). It measured the soil water content based on the travel time of high frequency electromagnetic pulse through the soil.

Harvest measurements

At physiological maturity, the crops were harvested from the net plots to calculate grain yield that was then calculated on hectare basis at 12.5% moisture for maize and 9% moisture for legumes. The biomass harvested was weighed, and later retained as surface mulch in deep bed and pit planting plots and incorporated later into the soil during ridging in conventional plots.

Statistical analysis

Analysis of variance was used to determine the effect of treatments on maize yield, legume yield and total grain yield. Statistical analyses were performed using GenStat discovery 19th edition.

Yield data were tested for normality and homogeneity and showed normal population distribution and homogeneity of the variances.

3.0. Results and Discussion

3.1. Grain and Biomass Yield

On-station Maize Grain and Biomass Yields

The analysis of variance for on-station showed that there were significant differences ($p<0.05$) for the main effect of tillage systems for maize grain yield at Bolero, Bvumbwe, Chitala and Zombwe (Table 1). For the main effect of cropping system, significant differences ($p<0.05$) were observed at Bvumbwe and Zombwe while only at Chitala were the significant differences ($p<0.05$) for the interaction between the cropping and tillage system observed. On the other hand, significant differences ($p<0.05$) for biomass yield were only observed at Bvumbwe (Table 1). Except for Chitedze where there were no significant differences ($p<0.05$) for grain yield, the results from all the other stations show that deep bed farming system gave significantly ($p<0.05$) higher yields compared to conventional tillage without box ridges (CT) and pit planting (Table 2). Deep bed (DBF) increased maize grain yield be 72%, 51%, 21% and 30% compared with CT at Bolero, Chitala, Zombwe and Bvumbwe respectively. On the other hand, DBF increased maize grain yield be 125%, 35%, 84% and 98% compared with CT at Bolero, Chitala, Zombwe and Bvumbwe, respectively. Conventional tillage with Box ridges (SMZ-CT) increased biomass yield by 111% compared with pit planting with legumes (MZL-PT) at Bolero while at Bvumbwe deep bed with maize legume (MZL-DB) increased biomass yield by 124% compared with (MZL-PT).

Table 1. Analysis of variance (ANOVA) for maize grain and biomass yield for on-station sites

	Sites				
	Bolero	**Bvumbwe**	**Chitala**	**Chitedze**	**Zombwe**
Source of Variation	**Maize grain (F-pr)**				
Cropping system	NS	0.013	NS	NS	0.003
Tillage System	< 0.001	0.003	< 0.001	NS	< 0.001
Cropping system x Tillage System	NS	NS	0.032	NS	NS
	Maize biomass (F-pr)				
Cropping system	NS	0.014	NS	NS	NS
Tillage System	0.05	NS	NS	NS	NS
Cropping system x Tillage System	NS	0.033	NS	NS	NS

Table 2. Mean maize grain and biomass yields (kg ha^{-1}) for on-station sites

		Grain				**Biomass**			
Site		**Tillage**							
	Cropping system	**CT**	**CT-B**	**DB**	**PT**	**CT**	**CT-B**	**DB**	**PT**
Bolero	MZ-L	8296^{b}	10444^{a}	11951^{a}	6667^{b}	7111^{a}	6285^{ab}	5630^{b}	3481^{c}
	SMZ	6222^{b}	11556^{a}	12988^{a}	4406^{b}	5383^{b}	7333^{a}	5778^{b}	4470^{b}
	Mean	7259	11000	12470	5537	6247	6809	5704	3975.5
	LSD	1915				1445			
	CV	24.04				28.41			
Chitala	MZ-L	9967^{e}	12481^{cd}	15445^{a}	9979^{e}	15558	17646	12432	16281
	SMZ	9443^{e}	13237^{bc}	13818^{b}	11715^{d}	15909	15744	14225	16390
	Mean	9705	12859	14631.5	10847	15733.5	16695	13328.5	16335.5
	LSD	775				2067			
	CV	7.28				15.18			
Chitedze	MZ-L	13727	12806	13737	12323	18072	14894	19106	14541
	SMZ	11972	14463	12723	12439	14049	17722	15933	14393
	Mean	12849.5	13634.5	13230	12381	16060.5	16308	17519.5	14467
	LSD	2318				2211			
	CV	20.52				15.8			
Zombwe	MZ-L	8961^{b}	10376^{a}	10349^{a}	6988^{c}	8025	9829	10074	8111
	SMZ	7492^{b}	10929^{a}	9527^{a}	3829^{c}	7827	9370	9728	9273
	Mean	8226.5	10652.5	9938	5408.5	7926	9599.5	9901	8692
	LSD	1285				1672			
	CV	17.21				20.76			
Bvumbwe	MZ-L	11718^{a}	9394^{b}	12156^{a}	6060^{c}	10617^{a}	8675^{b}	12025^{a}	5370^{d}
	SMZ	6120^{b}	9354^{a}	10982^{a}	5633^{b}	6667^{c}	8593^{bc}	5728^{cd}	7230^{bcd}
	Mean	8919	9374	11569	5846.5	8642	8634	8876.5	6300
	LSD	1832				1931			
	CV	23.03				26.47			

On-Farm Maize Grain and Biomass Yields

Analysis of variance (ANOVA) for maize grain and biomass yields for on-farm show significant differences *($p<0.05$)* for only the main effect of tillage system at both Bazale, Chinguluwe and Mtunthama (Table 3). Besides, it is only at Chinguluwe where significant difference *($p<0.05$)* for the main effect of tillage system was observed biomass yields. Similar to on-station results, DBF gave significantly *($p<0.05$)* higher maize grain yield compared with CT and PT. DBF gave 53%, 24% and 42% more maize grain yields at Bazale, Chinguluwe and Mtunthama, respectively (Table 4). On the other hand, DBF gave 77%, 64% and 43% more maize grain yields compared with PT at Bazale, Chinguluwe and Mtunthama, respectively. Biomass yield was 36% more for DBF compared with PT at Chinguluwe.

Deep bed farming system and conventional tillage with box ridges were superior in improving both maize grain and biomass yields compared to conventional tillage without box ridges and pit planting. Since there is also presence of box ridges and surface residue cover under deep bed farming system, the possible explanation for higher yields would be enhanced moisture retention, increased organic matter and reduced evaporation under deep bed farming system. Increase in organic matter due to surface residue cover besides minimal tillage result in increased moisture retention in farming systems (Simwaka *et al.,* 2020). There was minimal tillage under deep bed in the second season compared to deep tillage under conventional system although box ridges gave an advantage to the other conventional tillage that were constructed with box ridges. During the mid-season which was the critical vegetative to flowering stage of maize, there were heavy rains, this prompted over flooding of the planting pits that's resulting into lodging of the maize plants. This subsequently affected the yields. It has been reported that planting pits favor drier areas with moderate rain season. Heavy rains result into flooding of the pits leading to lodging and plant diseases (Bunderson *et al.,* 2011). On the other hand it has been reported that due to continuous tillage under conventional tillage, it leads to lower maize yields, low organic matter inputs, and increased leaching of valuable nutrients and increased evapotranspiration and surface runoff (Ngwira et al. 2013).

Table 3. Analysis of variance (ANOVA) for maize grain and biomass yield for on-farm sites

	Site		
	Bazale	**Chinguluwe**	**Mtunthama**
Source of Variation	**Maize grain (F-pr)**		
Cropping system	NS	NS	NS
Tillage System	0.003	0.039	< 0.001
Cropping system x Tillage System	NS	NS	NS
	Maize biomass (F-pr)		
Cropping system	NS	NS	NS
Tillage System	NS	0.041	NS
Cropping system x Tillage System	NS	NS	NS

3.2. Soil Moisture Content

Analysis of variance showed that there were significant differences *($p<0.05$)* for soil moisture content at Bvumbwe, Chitala and Mtunthama (Table 6). At Chitala, DBF increased soil moisture content by 30% compared with CT (Table 7). Meanwhile, at Bvumbwe, DBF increased soil moisture by 49% and 65% compared with CT and PT, respectively. At Mtunthama, DBF increased soil moisture content by 238% and 166% compared with CT and PT, respectively. The results on soil moisture for both station and on-farm are consistent. Chitala and Balaka fall within the low altitude agro-ecology that is the hottest agro-ecology of the three. Deep bed and CT-B both have box ridges that hold rainwater while planting pits are known to contain the water within the basin. Therefore, compared with CT that had open ridges, this could imply that the former tillage systems conserved more moisture even during the time of peak evapotransipiration. Though this was not quantified in the current study. There is need therefore to do further studies on the effect of evapotranspiration on soil moisture conservation by comparing these same tillage systems. The results are also consistent with the grain and biomass yields for PT tillage system. PT accumulated more water due to heavy rains during the cropping season that could have contributed to poor soil aeration and hence low yields. More water accumulation in the PT system conversely resulted in increased soil water retention.

Table 4. Mean maize grain and biomass yield (kg ha^{-1}) for on-farm sites

		Grain				**Biomass**			
Site		**Tillage**							
	Cropping system	**CT**	**CT-B**	**DB**	**PT**	**CT**	**CT-B**	**DB**	**PT**
Mtunthama	MZ-L	8776^{b}	8387^{b}	12394^{a}	6941^{c}	9022	8485	7763	8148
	SMZ	7528^{c}	10692^{b}	12578^{a}	7161^{c}	9575	9770	7481	7959
	Mean	8152	9539.5	12486	7051	9298.5	9127.5	7622	8053.5
	LSD	1452				1025			
	CV (%)	17.9				13.74			
Chinguluwe	MZ-L	10096^{a}	10423^{a}	11036^{a}	5744^{b}	6623^{a}	6921^{a}	7495^{a}	3941^{d}
	SMZ	8474^{b}	11236^{a}	11972^{a}	8298^{b}	7006^{bc}	8159^{a}	$7528a^{b}$	6170^{c}
	Mean	9285	10829.5	11504	7021	6814.5	7540	7511.5	5055.5
	LSD	1963				1059			
	CV (%)	22.63				17.64			
Bazale	MZ-L	7659^{b}	6880bc	11521^{a}	6519^{c}				
	SMZ	7548^{b}	8741^{b}	10062^{a}	8545^{b}				
	Mean	7603.5	7810.5	10791.5	7532				
	LSD	1240							
	CV (%)	16.62							

Table 5. Analysis of variance (ANOVA) for soil moisture content (%) for all on-station and two on-farm sites

	On-station					On-farm	
	Bolero	Zombwe	Chitedze	Chitala	Bvumbwe	Mtunthama	Bazale
Source of Variation	F-pr						
Cropping system	NS	NS	NS	NS	NS	NS	NS
Tillage System	NS	NS	NS	0.006	<.001	<.001	NS
Cropping system x Tillage System	NS	NS	NS	NS	NS	NS	NS

Table 6. Mean soil moisture content (%) for all on-station and two on-farm sites

		Tillage System			
Site	**Cropping System**	**CT**	**CT-B**	**DB**	**PT**
Bolero	MZ-L	12.4	16.5	17.1	30.8
	SMZ	14.1	17.6	16.1	14.5
	Mean	13.25	17.05	16.6	22.65
	LSD	17.77			
	CV	27.6			
Zombwe	MZ-L	28.28	37.96	35.76	34.33
	SMZ	24.53	30.95	31.5	19.14
	Mean	26.405	34.455	33.63	26.735
	LSD	18.76			
	CV	7.4			
Chitedze	MZ-L	40	34.1	35.4	31.7
	SMZ	36.6	27.2	34.9	29.5
	Mean	38.3	30.65	35.15	30.6
	LSD	12.78			
	CV	21.7			
Chitala	MZ-L	33b	41a	53a	54.3a
	SMZ	35.7b	39.1a	46.5a	52.1a
	Mean	34.35	40.05	50.2	53.2
	LSD	15.05			
	CV	19.3			
Bvumbwe	MZ-L	9.4b	10.6b	16.5a	9.9b
	SMZ	11.2b	8.4b	16.9a	10.1b
	Mean	10.3	9.5	16.7	10
	LSD	4.35			
	CV	21.4			
Mtunthama	MZ-L	8.2b	9b	20.3a	7.5b
	SMZ	5.9b	6.5b	19.6a	7.5b
	Mean	7.05	7.75	19.95	7.5
	LSD	4.86			
	CV	12.1			
Bazale	MZ-L	8.4	15	8.6	19
	SMZ	12.2	11.7	12.4	14.3
	Mean	10.3	13.35	10.5	16.65
	LSD	8.04			
	CV	48.8			

Conclusion

The study revealed that deep bed farming system and conventional tillage with box ridges were superior in improving both maize grain and biomass yields compared to conventional tillage without box ridges and pit planting in all the three agro-ecologies. Deep bed and conventional tillage with box ridges also increased biomass yield in the low agro-ecology. Similar to crop yield, Soil moisture was also increased under deep bed and pit planting systems especially in the low and high altitude agro-ecologies under on station management and only for the mid altitude agro-ecology under farmers management. In general, Deep bed farming can be a new good technology that may be promoted among farmers in Malawi as it increases both maize and biomass yields and enhances soil moisture retention. The increased biomass production under deep bed farming system may lead to increased soil organic matter build up through enhanced microbial activity in the long run.

Recommendation

Having evaluated the deep bed farming system for two seasons in the three agro ecologies of Malawi and having observed the similar trend in the performance of the technology, it is our recommendation that DBF should be earmarked for a possible release for famers use in Malawi. Another recommendation would be to maintain the sites to monitor long-term sustainability impacts of the DBF compared with CT and PT.

Acknowledgement

The authors sincerely would like to thank Tiyeni Limited for funding the research work and all the technicians and field officers whom were involved throughout the implementation process.

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