Paths of Influence Among Components of Yield in Sorghum (*Sorghum bicolor (L) Moench, cv Tegemeo*) Grown in the Semi Arid area of Dodoma Region, Tanzania.

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Abstract

*Sorghum is a food security crop in tropical marginal areas. Improvement strategies for yield under such conditions are important. Genetic improvement for yield is done through improvement of its components. Due to yield component compensation, this improvement strategy is made less rewarding. It is therefore important to know compensatory mechanisms existing for better improvement strategies. Studies on the nature of component compensations in sorghum are limited and virtually lacking under Tanzanian conditions. A field experiment was conducted to investigate the nature of interrelationships among components of yield in sorghum at the experimental plots of Hombolo Research Station in the semi-arid zone of Dodoma Region, Tanzania. Six treatment combinations of rain water harvesting techniques and fertilizer were laid out in a randomized complete block design (RCBD) with four replications during the growing season of 1996/97. Number of grains was an important component which was significantly correlated (r=0.982***) with grain yield and had a high positive direct effect (0.979) on yield. Average grain weight was not important in influencing yield of sorghum. Plant biomass had a negative direct effect (-1.2997) on average grain weight but was not important in influencing number of grains. Plant height and percent light intercepted directly influenced number of grains and average grain weight negatively. The negative influence (- 0.8712) of plant height on number of grains was compensated to a low relationship (r= -0.337) mainly by its positive indirect influence (0.3780) through light interception. Improvement strategies should aim at shorter plants with more grains, of lesser canopy development and biomass in these semi arid areas.*

Keywords: Biomass, component compensation, grain number, light interception, plant height, semi arid, sorghum

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Introduction

Sorghum is one of the food security crops particularly in marginal areas where moisture is a limiting factor. Thus, improvement strategies must be sought to increase productivity of this crop under such conditions. One of the strategies for increasing yield is the improvement of components of yield. However, in a system of variable interrelations, components interact in different ways resulting to limited gains in yield upon improvement of specific variables (Adams, 1967).

Component compensation mechanisms existing among yield components undermine the component improvement strategy since the advantage gained from improving one variable will be undermined by a sacrife of another variable Yet, genetic improvement for yield through a component improvement approach remains the only option due to the polygenic nature of yield. On the other hand, Evans and Wardlaw (1976) asserted that one reason for the success of cereals as crops is their capacity for yield component compensation. Thus, an investigation of such relationships will aid in formulating appropriate breeding/selection indices for better gains.

Relatively few studies, for instance by El- Rassas *et al.*,(1990), Patil *et al.*, (1990, 1995), Petdukhe *et al.*, (1992)), and Asthna *et al.*, (1996, 1997), have been conducted to investigate the nature of interrelationships and compensation mechanisms operating among components of yield in sorghum. Such studies on sorghum are virtually lacking under Tanzanian local conditions. It is therefore important to investigate the nature of interrelationships existing among components of yield using the crop grown under the local conditions of culture. This will aid in formulating appropriate improvement strategies based on component selection approach.

The present study was set to investigate the nature of component associations in sorghum using the commercial cultivar "Tegemeo" under different regimes of water harvesting techniques and fertilizer in the semi-arid area of Dodoma Region, Tanzania.

Materials and Methods

Experimental site

The experiment was conducted at the experimental plots of Hombolo Research Station (5° 45' S, 35° 57' E and 1037 m asl) in Dodoma Region, Tanzania during the 1996/1997 growing season. The experimental field had one direction of difference, sloping slightly eastward and therefore, blocking across the field was necessary to reduce experimental error.

Experimental design

Six treatments, which were a basis of variation among and within components of yield, comprising different water conservation techniques (tillage practices) and fertilizer were arranged in plots in randomized complete block design (RCBD) with four replications. These were: no primary tillage (NPT) with no fertilizer (control); no primary tillage with 30 t/ha of farm yard manure (FYM); shallow depth of tillage with tied ridging without fertilizer; deep depth of tillage with tied ridging without fertilizer; shallow depth of tillage with tied ridging and 30 t/ha FYM; deep depth of tillage with tied ridging and 30 t/ha FYM. Each block had a full set of treatment combinations used in the study.

Seeds of sorghum (cv Tegemeo) were directly sown on ridges on November 30th, 1996 at a spacing of 30 x 100 cm in deep tillage ridges and 40 x 75 cm in shallow tillage ridges so as to get a recommended population of 33,333 plants/ha in all treatments. Thinning was done to three plants per hill at two weeks after emergence and appropriate husbandry practices were done to control weeds and insect pests during the growing cycle.

Data collection

Data were collected for plant height, biomass/hill, percent light intercepted, number of productive tillers/hill, leaf area index (LAI) at panicle emergence; 1000 grain weight, number of grains /hill, and grain yield/hill at harvest. Mean plant height for each plot was taken from a random row in a plot and all heights of main shoot in a hill measured at full panicle emergence. The average height of all the plants in a raw was taken as the mean plant height for a plot. Five random hills in a plot were taken from which plant biomass, productive tillers, leaf area index, light interception, number of grains and grain weight were recorded. Average values for the five plants (values/hill) were taken as mean plot values for these variables. One thousand grain weight was weighed from 1000 grains sampled from a harvested area of 6 m x 12 m after sundrying the panicles for three days. In each plot, weight of 2 samples of 1000 grains were recorded and averaged.

Leaf area index was measured from the random sample of 5 hills by use of an automatic leaf area index portable machine. The device was placed at the ground level of the bottom of the canopy at each of the five random hills and average value computed for a plot. The percent light intercepted by the canopy was measured by a light measuring device in wave length units. In each of the five hills in a plot, the equipment was placed above and below the canopy at ground level and measurements of solar radiation recorded. The percentage of light intercepted by the canopy was calculated as:

$$\frac{ACR - BCR}{ACR} \times 100$$

Where ACR = Above canopy reading; BCR = Below Canopy Reading

A variance analysis was computed for each variable and plot means were used to calculate simple correlation coefficients between pairs of variables.

Path coefficient analysis

A path analysis was done to discern the direct influence of variables upon others and separation of the correlation coefficients into components of direct and indirect effects. The method is simply a standardized partial regression coefficient and its use requires a cause and effect situation among the variables.

Eight variables were included in the path coefficient analysis and the nature of the causal system is represented diagrammatically in Figure 1. In the path diagram, the double arrowhead lines indicate mutual association as measured by correlation coefficients, r_{ij}, and the single arrowhead lines represent direct influence as measured by path coefficients, P_{ij}. The direct effect, Pij, implies an effect a variable has on another when other variables in consideration do not vary. The indirect effect of a variable through its influence on another variable is designated rij Pij. This implies an effect a variable has through its influence on another when other variables in consideration vary.

The total of direct effect and indirect effects of a variable upon another adds up to the simple correlation coefficient, rij. The X variable consists of all residual factors that influenced a variable which includes sampling error or the effect of other variables not included in the model. In the path diagram, 1000 grain weight and number of grains were considered as the first order components since they are considered to affect yield directly, while the other components viz. plant height, biomass, light interception, productive tillers, and LAI were considered as second order components because they affect grain variables before final yield is determined (Duarte and Adams, 1972).

The path coefficients were obtained by the simultaneous solution of the following equations which express the basic relationships between correlation and path coefficients as described by Wright (1921) and revised by Dewey and Lu (1959):

Second order components on 1000 grain weight

$$r_{16} = P_{16} + r_{12}P_{26} + r_{13}P_{36} + r_{14}P_{46} + r_{15}P_{56}$$

$$r_{26} = r_{12}P_{16} + P_{26} + r_{23}P_{36} + r_{24}P_{46} + r_{25}P_{56}$$

$$r_{36} = r_{13}P_{16} + r_{23}P_{26} + P_{36} + r_{34}P_{46} + r_{35}P_{56}$$

$$r_{46} = r_{14}P_{16} + r_{24}P_{26} + r_{34}P_{36} + P_{46} + r_{45}P_{56}$$

$$r_{56} = r_{15}P_{16} + r_{25}P_{26} + r_{35}P_{36} + r_{45}P_{46} + P_{56}$$

$$1 = P^2_{x6} + P^2_{16} + P^2_{26} + P^2_{36} + P^2_{46} + P^2_{56} + 2P_{16}r_{12}P_{26} + 2P_{16}r_{13}P_{36} + 2P_{16}r_{14}P_{46} + 2P_{16}r_{15}P_{56} + 2P_{26}r_{23}P_{36} + 2P_{26}r_{24}P_{46} + 2P_{26}r_{25}P_{56} + 2P_{36}r_{34}P_{46} + 2P_{36}r_{35}P_{56} + 2P_{46}r_{45}P_{56}$$

Second order components on number of grains

$$r_{17} = P_{17} + r_{12}P_{27} + r_{13}P_{37} + r_{14}P_{47} + r_{15}P_{57}$$

$$r_{27} = r_{12}P_{17} + P_{27} + r_{23}P_{37} + r_{24}P_{47} + r_{25}P_{57}$$

$$r_{37} = r_{13}P_{17} + r_{23}P_{27} + P_{37} + r_{34}P_{47} + r_{35}P_{57}$$

$$r_{47} = r_{14}P_{17} + r_{24}P_{27} + r_{34}P_{37} + P_{47} + r_{45}P_{57}$$

$$r_{57} = r_{15}P_{17} + r_{25}P_{27} + r_{35}P_{37} + r_{45}P_{47} + P_{57}$$

$$1 = P^2_{x7} + P^2_{17} + P^2_{27} + P^2_{37} + P^2_{47} + P^2_{57} + 2P_{17}r_{12}P_{27} + 2P_{17}r_{13}P_{37} + 2P_{17}r_{14}P_{47} + 2P_{17}r_{15}P_{57} + 2P_{27}r_{23}P_{37} + 2P_{27}r_{24}P_{47} + 2P_{27}r_{25}P_{57} + 2P_{37}r_{34}P_{47} + 2P_{37}r_{35}P_{57} + 2P_{47}r_{45}P_{57}$$

First order components on grain yield

$$r_{68} = P_{68} + r_{67}P_{78}$$

$$r_{78} = r_{67}P_{68} + P_{78}$$

$$1 = P^2_{x8} + P^2_{68} + P^2_{78} + 2P_{68}r_{67}P_{78}$$

Results and Discussion

Second order components on 1000 grain weight

The paths of influence of the second order components on 1000 grain weight are shown in Table 1 and Figure 1. Leaf Area Index (LAI) (1.2399) and number of productive tillers per hill (1.0015) had high positive independent (direct) effects on 1000 grain weight. This suggests that holding other variables constant, increased LAI and number of productive tillers can increase average seed weight.

Although the number of productive tillers had a high positive direct effect on 1000 grain weight, this was reduced to a low but positive correlation ($r = 0.325$) mainly by the negative indirect effects through biomass (-0.5446) and leaf area index (-0.5168). Had it not been for the negative indirect effects through biomass and LAI, the correlation between productive tillers and 1000 grain weight would have been high and positive. On the contrary, productive tillers and plant height interacted positively (0.3949) in influencing 1000 grain weight and this was due to the cross product of the negative correlation ($r = -6568$) between tillering and height and the negative direct effect (-0.6012) of height on average grain weight.

The high and positive independent contribution of LAI on 1000 grain weight was reduced to a low correlation with 1000 grain weight ($r = 0.112$) by the cumulative indirect effects through biomass (-0.5201), productive tillers (-0.4174) and plant height (-0.2230). Thus, biomass, productive tillers and plant height interacted negatively with LAI in determining average grain weight. Path coefficient analysis therefore reveals the importance of leaf area index (LAI) and productive tillers in influencing 1000 grain weight directly. Their simple correlation with average grain weight were however low and not significant.

The lack of significant relationships between LAI and productive tillers with average grain weight would imply that these variables were apparently not important in determining average grain weight. However, with the correlation coefficients partitioned into their components, one can clearly see what is contributing to the observed relationship. The direct effects point out the obvious fact that with other variables held constant, increasing LAI and number of productive tillers will increase average grain weight. An examination of the paths of influence indicate that more subtle indirect effects play more important roles and mask the direct influences. The study shows that in order for LAI and tillering to have good relationships with average grain weight, breeding and agronomic practices should set to improve the relationships between biomass and average grain weight and between tillering and LAI.

Table 1: Direct and indirect effects of second order components of yield on 1000 grain weight

(a)	**Plant height Vs 1000 Grain weight, r_{16}**		=	-0.331
	Direct effect, P_{16}			-0.6012
	Indirect via biomass, r_{12} P_{26}			0.1226
	Indirect via % light intercepted, r_{13} P_{36}			0.3455
	Indirect via productive tillers, r_{14} P_{46}			-0.6578
	Indirect via LAI, r_{15} P_{56}			0.4600
		Total r	=	-0.3309
(b)	Biomass Vs 1000 grain weight, r_{26}		=	-0.235
	Direct effect, P_{26}			-1.2997
	Indirect via plant height, r_{12} P_{16}			0.0567
	Indirect via % light intercepted, r_{23}.P_{36}			0.0917
	Indirect via productive tillers, r_{24} P_{46}			0.41196
	Indirect via LAI, r_{25} P_{56}			0.4962
		Total r	=	-0.2355
(c)	% light intercepted Vs 1000 grain weight, r_{36}		=	-0.004
	Direct effect, P_{36}			-0.5470
	Indirect via plant height, r_{13} P_{16}			0.3797
	Indirect via biomass, r_{23} P_{26}			0.2180
	Indirect via productive tillers, r_{34} P_{46}			0.0186
	Indirect via LAI, r_{35} P_{56}			-0.0735
		Total r	=	-0.0042
(d)	Productive tillers Vs 1000 grain weight, r_{46}		=	0.325
	Direct effect, P_{46}			1.0015
	Indirect via plant height, r_{14} P_{16}			0.3949
	Indirect via biomass, r_{24} P_{26}			-0.5446
	Indirect via % light interception, r_{34} P_{36}			-0.0102
	Indirect via LAI, r_{45} P_{56}			-0.5168
		Total r	=	0.3248
(e)	LAI Vs 1000 grain weight, r_{56}		=	0.112
	Direct effect, P_{56}			1.2399
	Indirect via plant height, r_{15} P_{16}			-0.2230
	Indirect via biomass, r_{25} P_{26}			-0.5201
	Indirect via % light intercepted, r_{35} P_{36}			0.0324
	Indirect via productive tillers, r_{45} P_{46}			-0.4174
		Total r	=	0.1118

P_{x6} = 0.1700

Biomass (-1.2997), plant height (-0.6012) and % light intercepted (-0.5470) had high and negative direct effects on the average weight of grain implying that if the other variables do not change, these components can have a detrimental effect on 1000 grain weight (Table 1). Although the direct influence of biomass on 1000 grain weight was quite high and negative, its total correlation with yield (r = -0.235) was reduced to a low and non significant value. This was attributed to compensations by the positive indirect effects through tillering (0.4196) and LAI (0.4962). These indirect effects were due to the positive relationships between the variables (productive tillers and LAI) with average grain weight and their high and positive direct effects on the latter. The negative independent contributions of biomass and plant height on average grain weight could be attributed to competitive growth/developmental effects among reproductive and vegetative components. Investigations by Asthna *et al;* (1996) however, indicated that plant height had a high and positive direct effect on 1000 grain weight while evaluating 52 sorghum genotypes. The conflicting findings could be attributed to differential environments and accessions as determined by type of treatments in the separate studies.

The negative independent effect of plant height (-0.6012) and the indirect effect through tillering (-0.6578) on 1000 grain weight were reduced to a low and non significant correlation (r = -0.331) mainly by the cumulative positive indirect effects through LAI (0.4600) and % light intercepted (0.3455). Thus , plant height interacted negatively with tillering in influencing average weight of grain while the interactions with % light intercepted and LAI were positive.

The high and negative direct effect of % light intercepted on 1000 grain weight (-0.5470) was reduced to a low and non significant correlation (r = -0.004) mainly by the cumulative positive indirect effects through plant height (0.3797) and biomass (0.2180). The positive indirect effects were however, attributed by cross product of the negative relationships of the variables (plant height and biomass) with % light intercepted and the negative direct effects of these variables on the average weight of grain. Thus, the proportion of light intercepted interacted in a positive manner with plant height and biomass in influencing 1000 grain weight. Thus, compensatory mechanisms existing among components of yield in sorghum have added to an advantage of biomass, plant height and % light intercepted not to have detrimental relationships with average grain weight. The findings are consistent with the observations of Evans and Wardlaw (1976) who coined that one reason for the success of cereals as crops is their capacity for yield component compensation.

Second order components on number of grains

The paths of influence (Table 2) indicate that although plant height (-0. 8712) and % light intercepted (-0.5995) had relatively high negative independent effects on the number of grains , these were lower than the residual (0.8923) suggesting that other variables not included in the model might be contributing to the effect on number of grains. It was observed that plant height, biomass, % light intercepted, productive tillers and LAI both had high independent contributions on average grain weight. However for number of grains produced , only plant height and % light inter-

Table 2: Direct and indirect effects of second order components of yield on number of grains

(a)	**Plant height Vs grains/hill, r_{17}**		=	-0.337
	Ditrect effect, P_{17}			-0.8712
	Indirect via biomass, r_{12} P_{27}			-0.0162
	Indirect via % light intercepted, r_{13}, P_{37}			0.3786
	Indirect via productive tillers, r_{14}, P_{47}			0.1209
	Indirect via LAI, r_{15} P_{57}			0.0510
		Total r	=	-0.3369
(b)	Biomass Vs grains/hill, r_{27}		=	0.332
	Direct effect, P_{27}			0.1717
	Indirect via plant height, r_{12} P_{17}			0.0822
	Indirect via % light intercepted, r_{23} P_{37}			0.1005
	Indirect via productive tillers, r_{24} P_{47}			-0.0771
	Indirect via LAI, r_{25} P_{57}			0.0551
		Total r	=	0.3324
(c)	% Light intercepted Vs grain/hill, r_{37}		=	-0.090
	Direct effect, P_{37}			-0.5995
	Indirect via plant height, r_{13} P_{17}			0.5502
	Indirect via biomass, r_{23} P_{27}			-0.0288
	Indirect via productive tillers, r_{34} P_{47}			-0.0034
	Indirect via LAI, r_{35} P_{57}			-0.0082
		Total r	=	-0.0897
(d)	Productive tiller Vs grain/hill, r_{47}		=	0.391
	Direct effect, P_{47}			-0.1841
	Indirect via plant height, r_{14} P_{17}			0.5722
	Indirect via biomass, r_{24} P_{27}			0.0719
	Indirect via % light intercepted, $r_{34}P_{37}$			-0.0112
	Indirect via LAI, r_{45} P_{57}			-0.0574
		Total r	=	0.3914
(e)	LAI Vs grains/hill, r_{57}		=	-0.005
	Direct effect, P_{57}			
	Indirect via plant height, $r_{15}P_{17}$			
	Indirect via biomass, r_{25} P_{27}			
	Indirect via % light intercepted, r_{35} P_{37}			
	Indirect via productive tillers, r_{45} P_{47}			
		Total r	=	-0.0046
	Px7 = 0.8923			

Table 3: Direct and indirect effects of first order components of yield on yield/hill

(a)	1000 grain weight Vs grain yield/hill, r_{68}		=	0.199
	Direct effect, P_{68}			0.1855
	Indirect via grains/hill, r_{67} P_{78}			0.0135
		Totar r	=	0.199
(b)	No grain/hill Vs grain yield/hill, r_{78}		=	0.982
	Direct effect, P_{78}			0.9796
	Indirect via 1000 grain weight, r_{67} P_{68}			0.0026
		Total r	=	0.9822
	P_{x8} = 0.3096			

cepted had relatively high independent effects although they were lower than the residual effect rendering them relatively unimportant in their influence on number of grains. Thus, 1000 grain weight and number of grains seem to be under the control of different developmental processes.

First order components on grain yield/hill

The paths of influence of the first order components on yield are shown in Table 3 and Fig. 1. The positive high significant correlation (r = 0.982**) between number grains/panicle in directly influencing grain yield of sorghum. The positive relationship between number of grains and yield observed in this study was also reported by other workers (e.g.. Patil *et al.*, 1990).

Conclusion

The present study indicates that the number of grains in sorghum is an

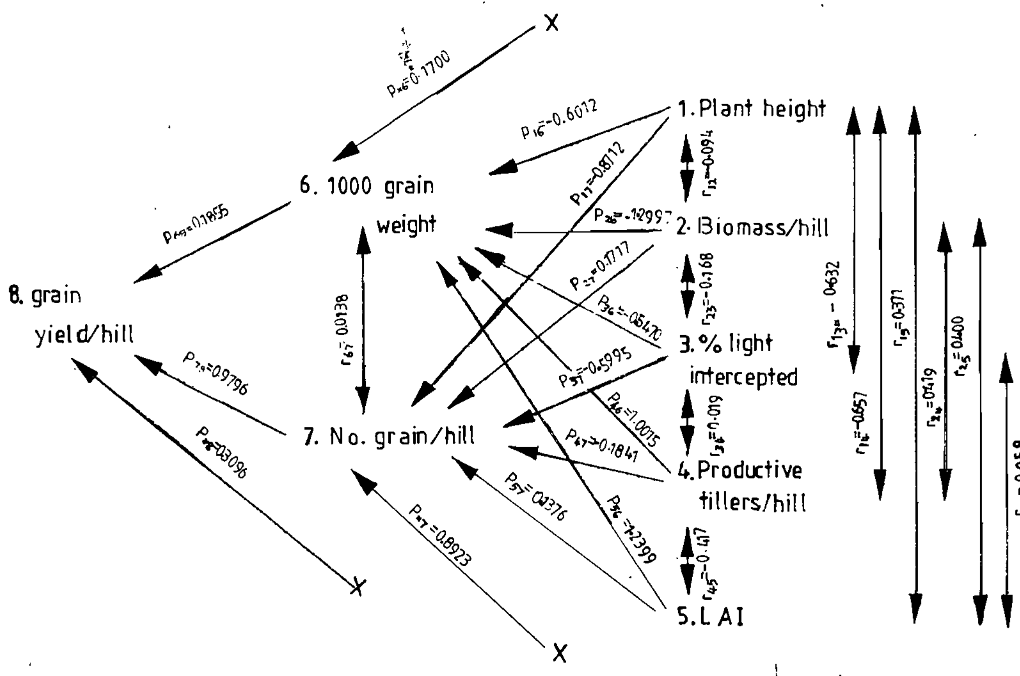

Figure 1: A path diagram and coefficient of factors influencing yield and components of yield in sorghum. Pij's are the direct effects and rij's are the correlation coefficients. X is the residual factor

of grains and yield/hill was largely contributed by its high direct effect (0.9796) on yield. This effect was higher than the residual value of 0.3096. However, 1000 grain weight was neither related nor was its independent effect important in determining yield/hill of sorghum. El-Rassas *et al.*, (1990) and Asthna *et al.*, (1997) also demonstrated the importance of number of important component which determines grain yield directly. On the other hand, average grain weight (1000 grain weight) was not important in influencing the yield of sorghum. The non-significant relationship observed between 1000 grain weight and number of grains suggests that increasing grain number in order to maximize yield will not be undermined by variation in average grain weight.

The study has revealed the importance of yield component compensation among components of yield in sorghum.

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