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CHARACTER ASSOCIATION AND PATH COEFFICIENT ANALYSIS IN RAINY SEASON SORGHUM (*Sorghum bicolor* (L.) Moench) VARIETIES AT SAMARU AND MAIGANA NORTHERN GUINEA SAVANNAH, NIGERIA

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ABSTRACT

A two-year field trial was conducted during the 2013 and 2014 rainy seasons at Institute for Agricultural Research (I.A.R) Farm, Samaru and Experimental Site of Kaduna Agricultural Development Agency (KADA) located at Maigana, Soba Local Government Area. Treatments consist of two sorghum varieties and four rates each of cow dung (0, 5, 10 and 15 t ha^{-1}) and inorganic nitrogen (0, 30, 60 and 90 kg N ha^{-1}). Correlation and path analysis was attempted for seven growth and yield characters. Grain yield showed highly significant and positive correlation with all the parameters in both years, locations and combined years except number of panicles plot^{-1} (0.028) at Maigana in the combined years of the experiment only. The variable that had the strongest positive direct effects on grain yield at both locations was grain weight panicle^{-1} (0.417) at Samaru and (0.565) at Maigana in the combined years only. The effects of the other variables were not consistent in both years at two locations and combined. The highest total percentage contribution to yield at Samaru in 2013 was by panicle weight plant^{-1}(152.06%) while in 2014 and combined seasons was by panicle length (57.79%) and grain weight panicle^{-1} (37.784%) respectively. The highest total percent contribution to yield at Maigana in 2013 was by number of panicles plot^{-1} (152.149%) while in 2014 and combined seasons was by panicle weight plant^{-1} (93.734%) and grain weight panicle^{-1} (52.716%) respectively. The interrelationships among these variables might be used in preparing a breeding programme to take advantage of their contributions to yield and develop high yielding sorghum varieties of improved characteristics.

Keywords: Correlation coefficient; path analysis; sorghum varieties; Yield.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) a staple food crop of the grass family classified botanically as Poaceae, genus Sorghum Moench (Poehlman and Sleper, 1995). It is an indispensable commodity in some semi-arid and arid regions of the world. Its centre of diversity is Ethiopia (Harlan, 1992) where it is similarly believed to have originated, having existed there between 5000 and 7000 years ago (Vavilov, 1951) the current distribution of the crop covers parts of Africa, India, and Southeast Asia, Australia and the United States (Mesfin and Tileye, 2013).

Its drought tolerant characteristic makes it adaptable to the semi-arid and arid regions of the world. It is ranked fifth most important cereal grain crop in the world (FAO, 2016). Its major contributors are its protein and energy requirements for millions of people, especially in the Sub-Saharan Africa and Asia (Orr *et al*., 2016). In Nigeria, where it had been the major staple food crop until it was succeeded by maize of recent, the lives of millions of people, depend on it as a source of food and beverages. The major commercial importance of the crop is its replacement of barley (Ilori *et al*., 1991) in the Nigerian brewery industries. Any crop with variable characters which their relationship and independence may be direct or indirect (Muhammad *et al*., 2003).

For crop yield components that contribute to it, exhibit these types of relationship. These very often yield components are variable and consequently make variable contributions to yield. One of the statistical tools used to partition such variable contributions into specific individual quantum is the path coefficient analysis. The partitioning being with or based on partitioning the coefficient correlations of the components which are further subjected to or analysed through mathematical equations for path analysis to measure the direct and indirect effects. Path analysis has been used widely in agriculture to assist in identifying traits that are useful as selection criteria to improve crop yield. Such studies reported on sorghum **(**Ramaling *et al*., 2016; Ezeaku *et al*., 2006; Iyanar *et al*., 2001)**.** Correlation coefficients and the contribution of some characters to the yield of various crops were reported by some workers such as maize (Sharifai *et al*., 2006) rice (Jibril *et al*., 2010) exemplifies or corroborates the assertion. Both the growth and yield components of crops as relate to their yields are greatly influenced by growth environment.

MATERIALS AND METHODS

The Study Area

Field trials were conducted during the 2013 and 2014 rainy seasons at the Institute for Agricultural Research (I.A.R) Farm, Samaru (11^0 11 N 09^0 38 E, 686 m above sea level) and the Kaduna Agricultural Development Agency (KADA) farm at Maigana (11^0 39’ N; 08^0 02’ E, 500m above sea level). Both experimental sites are in Kaduna State in the northern Guinea savanna ecological zone of Nigeria.

The meteorological data of the two areas (rainfall, temperatures, relative humidity and sunshine hour) were collected from the Meteorological Units of I.A.R, Samaru and KADA Maigana.

Treatments and Experimental Design

The treatments were laid out in a split plot design and replicated three times with the combinations of nitrogen and cowdung rates assigned in the main plots, while the varieties were allocated in the sub–plots. Each sub-plot had a gross size of 6.0m x 4.5m and a net plot of 6.0m x 1.5m. rows were spaced at 0.75m.

The two sorghum varieties (SAMSORG-17 and SAMSORG-44) used were sourced from IAR and were chosen based on their malting characteristics. They have 98% germination energy, which render them good for malting (Anonymous 1989; 2015).

Variety SAMSORG-17 takes 160 -180 days to mature and attains a height of 1.8 – 2.0 m. its grain is yellow in colour and has yield potential range of 2.5 – 3.0 tonnes ha^{-1}.

Variety SAMSORG-44 takes 95 -100 days to mature and attains a height range of 1.6 – 1.8 m. its grain is creamy white and has a potential grain yield range of 2.5 - 3.0 tonnes ha^{-1}.

Cultural Practice

The two varieties were established at 53,333 plants ha^{-1} using the spacing of 0.75 m x 0.25 m (1 plant per stand that gave 24 plants per ridge). Sowing was on 30thJune, 2013 and 27th July, 2014 at IAR, Samaru and 7th July, 2013 and 3rd July, 2014 at Maigana. The plants were maintained at the factorial combinations of four rates of inorganic nitrogen fertilizers (0,30,60 and 90 kg N ha^{-1}) and four rates of cowdung(0, 5, 10 and 15 tonnes ha^{-1}). Urea (46%N) was used to supply N and single superphosphate (SSP,18 % P_2O_5) to supply phosphorus (P) while murate of potash (MOP, 60 %, K_2O) were used to supply the blanket rates of 32 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1} for all the factorial treatment combinations. The N rates were split applied in two equal doses at sowing and 6 weeks after sowing (WAS).

Data were collected on grain yield and some yield parameters such as 50% days to heading, grain yield/ha, number of panicles $plot^{-1}$, panicle length, panicle weight $plant^{-1}$, grain weight $panicle^{-1}$ and 1000 grain weight. Simple correlation coefficients were calculated for each pair of yield component parameter using the formula according to Steel and Torries (1984).

$$r = \frac{SPxy}{\sqrt{SSx\ X\ SSy}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where r = Correlation coefficient between X and Y
SPxy = Sum of product xy
SSx = Sum of squares of x
SSy = Sum of squares of y

The direct and indirect effects were partitioned by path analysis as described by Dewey and Lu (1959) for 6 independent variables as follows:

$r_{1y}= P_1+r_{12} P_2+ r_{13}P_3 +r_{14}P_4 +r_{15}P_5 +r_{16}+P_6$ .... (2)
$r_{2y}= r_{12}P_1+ P_2 +r_{23}P_3 +r_{24}P_4 +r_{25}P_5 + r_{26}P_6$ .... (3)
$r_{3y}= r_{13}P_1 +r_{23}P_2 + P_3 +r_{34}P_4 +r_{35}P_5 + r_{36}P_6$ .... (4)
$r_{4y}= r_{14}P_1 +r_{24}P_2 + r_{34}P_3 +P_4 +r_{45}P_5 + r_{46}P_6$ ………………………………………… (5)
$r_{5y}= r_{15}P_1 +r_{25}P_2 + r_{35}P_3 +r_{45}P_4 + P_5 + r_{56}P_6$ .... (6)
$r_{6y}= r_{16}P_1 +r_{26}P_2 +r_{36}P_3 +r_{46}P_4 +r_{56}P_6 + P_6$ …………………………………...........(7).

The total percent direct contributions of variables gave the residual effect as given in the equation (8) as follows:

a. The residual effect:

$(Rx) =1-(r_{iy}P_1+r_{2y}P_2+r_{3y}P_3+r_{4y}P_4+r_{5y}P_5+r_{6y}P_6)$ .... (8)

RESULTS

The relationship between grain yield ha^{-1} and yield attributes of two sorghum varieties at Samaru in 2013 are shown in Table 1. The result showed that grain yield ha^{-1}is highly significantly correlated with days to 50 % heading (r=0.813**), number of panicles plot^{-1} (r=0.857**), panicle length (r=0.883**), panicle weight plant^{-1} (r=0.865**), grain weight panicle^{-1} (r=0.824**) and 1000 grain weight (r=0.825**). Among the highly positive significant correlations, panicle length had the strongest relationship (r = 0.883**) with grain yield ha^{-1} while weakest was between days to 50 % heading and grain yield ha^{-1} (r = 0.813**).

Table 1: Correlation coefficient among some growth and yield attributes of Sorghum at Samaru in2013, 2014 and combined analysis

2013 Yield Attributes	1	2	3	4	5	6	7
1.Grain Yield ha^{-1}	1.000						
2.Days to 50%heading	0.813**	1.000					
3.Number of panicle plot^{-1}	0.857**	0.768**	1.000				
4.Panicle length	0.883**	0.847**	0.867**	1.000			
5.Panicle weight plant^{-1}	0.865**	0.816**	0.703**	0.842**	1.000		
6.Grain weight panicle^{-1}	0.824**	0.814**	0.647**	0.825**	0.989**	1.000	
7.1000 grain weight	0.825**	0.817**	0.772**	0.928**	0.889**	0.882**	1.000
2014 Yield Attributes							
1.Grain Yield ha^{-1}	1.000						
2.Days to 50% heading	0.701**	1.000					
3.Number of panicle plot^{-1}	0.884**	0.790**	1.000				
4.Panicle length	0.872**	0.705**	0.804**	1.000			
5.Panicle weight plant^{-1}	0.403**	0.337**	0.467**	0.623**	1.000		
6.Grain weight panicle^{-1}	0.832**	0.573**	0.723**	0.753**	0.481**	1.000	
7.1000 grain weight	0.803**	0.780**	0.805**	0.881**	0.566**	0.682**	1.000
Combined Yield Attribute							
1.Grain Yield ha^{-1}	1.000						
2.Days to 50% heading	0.725**	1.000					
3.Number of panicle plot^{-1}	0.825**	0.721**	1.000				
4.Panicle length	0.854**	0.779**	0.729**	1.000			
5.Panicle weight plant^{-1}	0.468**	0.396**	0.255	0.659**	1.000		
6.Grain weight panicle^{-1}	0.717**	0.492**	0.421**	0.720**	0.743**	1.000	
7.1000 grain weight	0.750**	0.728**	0.792**	0.759**	0.288*	0.409**	1.000

* = values above 0.269 Significant at P = 0.05, ** = values above 0.320 highly Significant at P = 0.01

The relationship between grain yield ha^{-1} and yield attributes of two sorghum varieties at Samaru in 2014 is shown in Table 1. It was observed that grain yield ha^{-1} highly significantly correlated with days to 50 % heading (r = 0.701), number of panicle plot^{-1} (r = 0.884**), panicle length (r = 0.872**), panicle weight plant^{-1} (r = 0.403**), grain weight panicle^{-1} (r = 0.832**) and 1000 grain weight (r = 803**). Among the highly positively significant correlations, number of panicle plot^{-1} had the strongest relationship (r = 0.884**) with grain yield ha^{-1} while that between panicle weight plant^{-1} and grain yield ha^{-1} (r = 0.403) was the weakest.

The relationship between grain yield ha^{-1} and yield variables of two sorghum varieties at Samaru in 2013 and 2014 is shown in Table 1. The result shows that grain yield ha^{-1} significantly and positively correlated with days to 50 % heading (r = 0.725**), number of panicle plot^{-1} (r = 0.825**), panicle length (r = 0.854**), panicle weight plant^{-1} (r = 0.468**), grain weight panicle^{-1} (r = 0.717**) and 1000 grain weight (r = 750**). Among the highly positively significant correlations, panicle length had the strongest relationship (r = 0.854**) with grain yield ha^{-1} while that between panicle weight plant^{-1} and grain yield ha^{-1} (r = 0.468**) was the weakest.

The correltion between grain yield ha^{-1} and yield attributes of two sorghum varieties at Maiganain 2013 is shown in Table 2. The result showed that grain yield ha^{-1} highly significantly correlated with days to 50 % heading (r=0.658**), number of panicles plot^{-1} (r=0.395**), paniclelength (r=0.531**), panicle weight plant^{-1} (r=0.624**), grain weight panicle^{-1} (r=0.473**) and 1000 grain weight (r=0.634**). Among the highly positive significant correlations, days to 50 % heading had the strongest relationship (r = 0.658**) with grain yield ha^{-1} while least was between days to 50 % heading and grain yield ha^{-1} (r = 0.395**).

Table 2: Correlation coefficient among some growth and yield attributes of Sorghum at Maigana 2013, 2014 and combined analysis

2013 Yield Attributes	1	2	3	4	5	6	7
1.Grain Yield ha^{-1}	1.000						
2.Days to 50%heading	0.658**	1.000					
3.Number of panicle plot^{-1}	0.395**	0.794**	1.000				
4.Panicle length	0.531**	0.858**	0.950**	1.000			
5.Panicle weight plant^{-1}	0.624**	0.833**	0.789**	0.835**	1.000		
6.Grain weight panicle^{-1}	0.473**	0.775**	0.810**	0.839**	0.931**	1.000	
7.1000 grain weight	0.634**	0.822**	0.844**	0.902**	0.944**	0.899**	1.000
2014 Yield Attributes							
1.Grain Yield ha^{-1}	1.000						
2.Days to 50%heading	0.703**	1.000					
3.Number of panicle plot^{-1}	0.914**	0.812**	1.000				
4.Panicle length	0.889**	0.695**	0.827**	1.000			
5.Panicle weight plant^{-1}	0.650**	0.656**	0.717**	0.814**	1.000		
6.Grain weight panicle^{-1}	0.861**	0.820**	0.942**	0.840**	0.835**	1.000	
7.1000 grain weight	0.781**	0.659**	0.755**	0.801**	0.798**	0.841**	1.000
Combined Yield Attributes							
1.Grain Yield ha^{-1}	1.000						
2.Days to 50%heading	0.507**	1.000					
3.Number of panicle plot^{-1}	0.028	0.572**	1.000				
4.Panicle length	0.737**	0.699**	0.276*	1.000			
5.Panicle weight plant^{-1}	0.685**	0.408**	0.015	0.751**	1.000		
6.Grain weight panicle^{-1}	0.706**	0.559**	0.374**	0.751**	0.822**	1.000	
7.1000 grain weight	0.772**	0.537**	0.027	0.865**	0.807**	0.727**	1.000

* = values above 0.269 Significant at P = 0.05, ** = values above 0.320 highly Significant at P = 0.01

The relationship between grain yield ha^{-1} and yield characters of two sorghum varieties at Maigana in 2014 is shown in Table 2. It was observed that grain yield ha^{-1} highly significantly correlated with days to 50 % heading (r = 0.703), number of panicle plot^{-1} (r = 0.914**), panicle length (r = 0.889**), panicle weight plant^{-1} (r = 0.650**), grain weight panicle^{-1} (r = 0.861**) and 1000 grain weight (r = 781**). Among the highly positively significant correlations, number of panicle plot^{-1} had the strongest relationship (r = 0.914**) with grain yield ha^{-1} while that between panicle weight plant^{-1} and grain yield ha^{-1} (r = 0.650) was the weakest.

The relationship between grain yield ha^{-1} and yield attributes of two sorghum varieties at Maigana in 2013 and 2014 is shown in Table 2. The result shows that grain yield ha^{-1} significantly and positively correlated with days to 50 % heading (r = 0.507**), panicle length (r = 0.737**), panicle weight plant^{-1} (r = 0.685**), grain weight panicle^{-1} (r = 0.706**), 1000 grain weight (r = 772**) while it was not significant to number of panicle plot^{-1} (r = 0.028). Among the highly positively significant correlations, 1000 grain weight had the strongest relationship (r = 0.772**) with grain yield ha^{-1} while that between the number of panicle plot^{-1} and grain yield ha^{-1} (r = 0.028) was the weakest.

Table 3: The direct and indirect contributions of the different growth and yield components to yield at Samaru

		Direct and Indirect contributions		Effects				
	2013	2	3	4	5	6	7	Total
2	Days to 50 % heading	**0.068007**	0.201982	0.337797	1.006246	-0.5731	-0.22793	0.813
3	Number of panicles plot^{-1}	0.05223	**0.262997**	0.345773	0.866901	-0.45552	-0.21538	0.857
4	Panicle length	0.057602	0.228019	**0.398816**	1.038308	-0.58084	-0.2589	0.883
5	Panicle weight plant^{-1}	0.055494	0.184887	0.335803	**1.233145**	-0.69631	-0.24802	0.865
6	Grain weight panicle^{-1}	0.055358	0.170159	0.329023	1.21958	**-0.70405**	-0.24607	0.824
7	1000 grain weight	0.055562	0.203034	0.370101	1.096266	-0.62098	**-0.27899**	0.825
	2014							
2	Days to 50 % heading	**-0.11378**	0.363739	0.33513	-0.07728	0.169654	0.023542	0.701
3	Number of panicles plot^{-1}	-0.08989	**0.460429**	0.382191	-0.10709	0.214066	0.024296	0.884
4	Panicle length	-0.08022	0.370185	**0.475362**	-0.14287	0.222949	0.02659	0.872
5	Panicle weight plant^{-1}	-0.03834	0.215021	0.29615	**-0.22932**	0.142415	0.017083	0.403
6	Grain weight panicle^{-1}	-0.0652	0.33289	0.357947	-0.1103	**0.296081**	0.020584	0.832
7	1000 grain weight	-0.08875	0.370646	0.418794	-0.1298	0.201927	**0.030182**	0.803
	Combined							
2	Days to 50 % heading	**-0.00896**	0.296602	0.264275	-0.07239	0.205253	0.040214	0.725
3	Number of panicles plot^{-1}	-0.00646	**0.411376**	0.247313	-0.04661	0.175633	0.043749	0.825
4	Panicle length	-0.00698	0.299893	**0.339249**	-0.12046	0.300371	0.041927	0.854
5	Panicle weight plant^{-1}	-0.00355	0.104901	0.223565	**-0.18279**	0.309966	0.015909	0.468
6	Grain weight panicle^{-1}	-0.00441	0.173189	0.244259	-0.13582	**0.417181**	0.022593	0.717
7	1000 grain weight	-0.00652	0.32581	0.25749	-0.05264	0.170627	**0.055239**	0.750

A path coefficient analysis was carried out to partition the contributions of each yield character to determine its direct and indirect contributions via other measured characters to the grain yield which otherwise referred to as the total contribution of a yield characters to grain yield using the path coefficient analysis in twolocations, years and combined.

The direct and indirect effects of the different yield characters on grain yield during the two seasons and the combined seasons at Samaru are shown in Table 3. The highest direct contribution to grain yield in 2013 was through the panicle weight plant^{-1} (1.2331) followed by panicle length (0.3988) and number of panicles plot^{-1} (0.2629) while grain weight panicle^{-1} (-0.7040) made the least direct effect. The highest indirect effect was from grain weight panicle^{-1} (1.2195) followed by 1000 grains weight (1.0962), panicle length (1.0383) and days to 50% heading(1.0062) via panicle weight plant^{-1}. The least indirect effect to yield was from number of panicles plot^{-1} through grain weight panicle^{-1} (-0.6963).

When the direct and combined effects were converted to percent contributions, it was observed that the individual contribution of 152.06%, 49.37%, 15.91%, 7.78% and 6.92% were from panicle weight plant^{-1}, grain weight panicle^{-1}, panicle length, 1000 grains weight and number of panicles plot^{-1} respectively (Figure 1). The days to 50% heading made the least percent contribution of 0.46%. The highest combined contribution to grain yield ha^{-1} of 82.82% was from the combination of panicle length via panicle weight plant^{-1} while the least was from panicle weight plant^{-1} via grain weight panicle^{-1} (-171.73%). And the highest total percentage contribution to yield was by panicle weight plant^{-1} (234.88%) from its direct contribution of 152.06% and its indirect contribution with panicle length of 82.82%. The percent unaccounted variability was 7.61%.

The highest direct contribution to grain yield in 2014 was through the panicle length (0.4753) followed by number of panicles of panicle plot^{-1} (0.4604) and grain weight panicle^{-1} (0.2960). while days to 50% heading (-0.1137) made the least direct effect. The highest indirect effect was from 1000 grains (0.4187) via panicle length followed by 1000 grains weight (0.3706) through, number of panicles plot^{-1}. The least indirect effect to yield was from panicle length through panicle weight plant^{-1} (-0.1428).

The direct and indirect effects of the different yield characters on grain yield when the two years were combined is presented in Table 3. Grain weight panicle^{-1} made the highest direct effect on grain yield (0.4171), followed by number of panicle plot^{-1} (0.4113) and panicle length (0.3392). Days to 50% heading had the least direct effect on yield (-0.0089). The highest combined indirect effect on yield was from the panicle weight plant^{-1} via grain weight panicle^{-1} (0.3099). the indirect effect of panicle length via days to 50% heading (-11.331) made the least contribution.

Figure 1= Path diagram relating the grain yield of sorghum to some yield components at Samaru in 2013

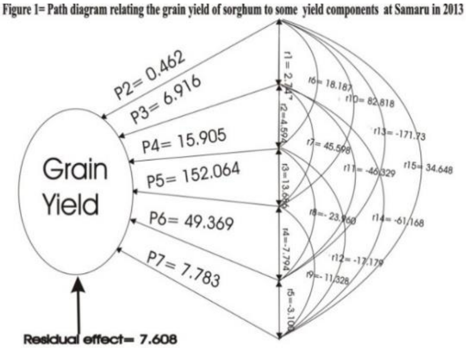


Figure 2= Path diagram relating the grain yield of sorghum to some yield components at Samaru in 2014

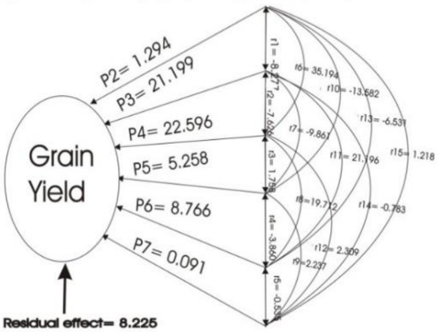
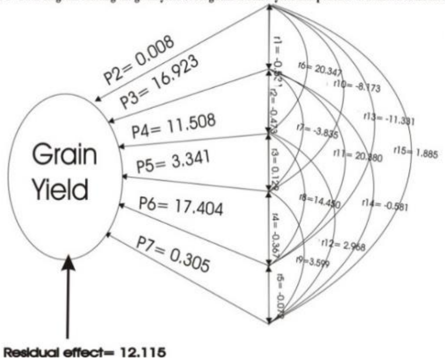


Figure 1= Path diagram relating the grain yield of sorghum to some yield components at Samaru combined



KEYS

P2 ...... P7 = Individual direct percent contributions of some yield characters to sorghum grain yield

Where P2= Days to 50% Heading
P3= Number of Panicles plot^{-1}
P4= Panicle Length
P5= Panicle weight plant^{-1}
P6= Grain weight Panicle^{-1}
P7= 1000 grains weight

r1 ... . R r15= indirect percent combined contributions of some yield Characters to sorghum grain yield via P2 ......P7

Figure 2 shows the individual and combined percent contributions of the yield components to grain yield ha^{-1}in 2014. It was observed that the individual contribution of 22.59%, 21.19%, 8.77% and 1.29% were from panicle length, number of panicles plot^{-1}, grain weight panicle^{-1} and days to 50% heading respectively. The 1000 grains weight made the least percent contribution of 0.09%. The combined percent contribution to grain yield ha^{-1} of 35.19% was found to be the highest from the combination of number of panicles plot^{-1}and panicle length. The least percent contribution of -13.58% was found to be made by panicle length via panicle weight. Total percentage contribution to grain yield of (57.79%) was by panicle length from its direct contribution of 22.59% and its indirect contribution with number of panicles plot^{-1}of 35.19%. The percent unaccounted variability was 8.23%.

Figure 3 shows the direct and combined effects of the yield components to grain yield in the combined years. It was observed that the direct individual percent contribution of 17.40%, 16.92%, 11.51%, 3.34% and 0.31% were from grain weight panicle^{-1}, number of panicles plot^{-1}, panicle length, panicle weight plant^{-1} and 1000 grains weight respectively. The combined contribution of panicle length and grain weight panicle^{-1} made the highest percent combined contribution of 20.38%, while the least combined percent contribution is from panicle weight plant^{-1} via grain weight panicle^{-1} (-11.33%). The total percentage contribution to grain yield of (37.78%) was by grain weight panicle^{-1} from its direct contribution of 17.40% and the indirect contribution of panicle length via grain weight of panicles^{-1} of 20.38%. The percent unaccounted variability was 12.12%.

The direct and indirect effects of the different yield characters on grain yield at Maigana during the two seasons and the combined Table 4 shows that the gretest direct contribution to grain yield in 2013 was through the 1000 grains weight (0.6641) followed by days to 50% heading (0.5125) and panicle weight plant^{-1} (0.4578) while number of panicles plot^{-1} (-0.8185) made the least direct effect. The highest indirect effect was from panicle weight plant^{-1} (0.6269) followed by panicle length (0.5990), grain weight panicle^{-1} (0.5970), number of panicle^{-1} (0.5605) and days to 50% heading (0.5458) via 1000 grains weight. The least indirect effect to yield was from 1000 grains weight through number of panicles plot^{-1} (-0.6903).

Table 4: The direct and indirect contributions of the different growth and yield components to yield at Maigana

		Direct and Indirect contributions			Effects			
	2013	2	3	4	5	6	7	Total
2	Days to 50 % heading	**0.512559**	-0.64991	0.365721	0.38141	-0.49768	0.545896	0.658
3	Number of panicles plot^{-1}	0.406972	**-0.81852**	0.404936	0.361263	-0.52015	0.560507	0.395
4	Panicle length	0.439775	-0.7776	**0.426248**	0.382325	-0.53878	0.599025	0.531
5	Panicle weight plant^{-1}	0.426961	-0.64581	0.355917	**0.457875**	-0.59786	0.626917	0.624
6	Grain weight panicle^{-1}	0.397233	-0.663	0.357622	0.426281	**-0.64217**	0.597032	0.473
7	1000 grain weight	0.421323	-0.69083	0.384476	0.432234	-0.57731	**0.664107**	0.634
	2014							
2	Days to 50 % heading	**-0.10734**	0.491076	0.397138	-0.24532	0.037087	0.130356	0.703
3	Number of panicles plot^{-1}	-0.08716	**0.604774**	0.472565	-0.26813	0.042605	0.149345	0.914
4	Panicle length	-0.0746	0.500148	**0.571421**	-0.30441	0.037991	0.158444	0.889
5	Panicle weight plant^{-1}	-0.07041	0.433623	0.465137	**-0.37396**	0.037765	0.157851	0.650
6	Grain weight panicle^{-1}	-0.08802	0.569697	0.479994	-0.31226	**0.045228**	0.166357	0.861
7	1000 grain weight	-0.07073	0.456604	0.457709	-0.29842	0.038037	**0.197808**	0.781
	Combined							
2	Days to 50 % heading	**0.195462**	-0.20719	0.161385	-0.0944	0.315863	0.13588	0.507
3	Number of panicles plot^{-1}	0.111804	**-0.36222**	0.063723	-0.00347	0.211329	0.006832	0.028
4	Panicle length	0.136628	-0.09997	**0.230879**	-0.17376	0.424353	0.218876	0.737
5	Panicle weight plant^{-1}	0.079748	-0.00543	0.17339	**-0.23138**	0.464471	0.2042	0.685
6	Grain weight panicle^{-1}	0.109263	-0.13547	0.17339	-0.19019	**0.56505**	0.183957	0.706
7	1000 grain weight	0.104963	-0.00978	0.199711	-0.18672	0.410792	**0.253036**	0.772

When the direct and combined effects were converted to percent contributions, it was observed that the individual contribution of 66.99%, 44.10%, 41.24%, 26.27% and 20.96% were from number of panicles plot^{-1} , 1000 grains weight, days to 50% heading and panicle weight plant^{-1} respectively (Figure 4). The panicle weight plant^{-1} made the least percent contribution of 18.17%. The highest combined contribution to grain yield ha^{-1} of 85.15% was from the combination of number of panicles plot^{-1} via panicle weight plant^{-1} while the least was from number panicles plot^{-1} via grain weight panicle^{-1} (-91.75%). And the highest total percentage contribution to yield was by number of panicles plot^{-1} (152.15%) from its direct contribution of 66.99% and its indirect contribution with panicle weight plant^{-1} of 85.15%. The percent unaccounted variability was 38.95%.

The gretest direct contribution to grain yield in 2014 was through the number of panicles plot^{-1} (0.0.6047) followed by panicle length (0.5714) and 1000 grains weight (0.1978). while days to 50% heading (-0.3739) made the least direct effect. The highest indirect effect was from grain weight panicle^{-1}, (0.5696) via number of panicles plot^{-1} followed by panicle length (0.5001) through, number of panicles plot^{-1}. The least indirect effect to grain yield was from grain weight panicle^{-1} through panicle weight plant^{-1} (-0.3122).

Figure 4= Path diagram relating the grain yield of sorghum to some yield components at Maigana in 2013

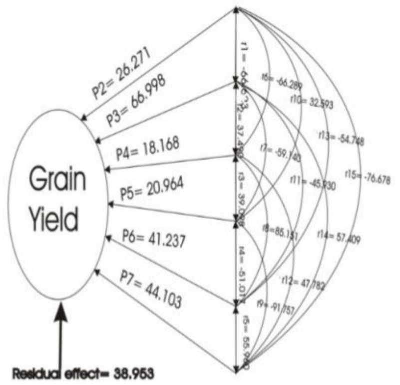


Figure 5= Path diagram relating the grain yield of sorghum to some yield components at Maigana in 2014

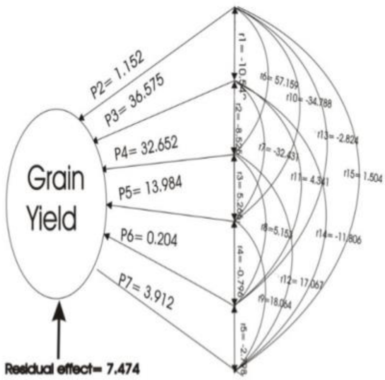
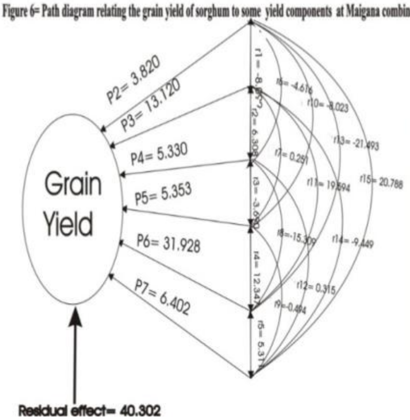


Figure 6= Path diagram relating the grain yield of sorghum to some yield components at Maigana combined



KEYS

P2 ...... P7 = Individual direct percent contributions of some yield characters to sorghum grain yield

Where P2= Days to 50% Heading
P3= Number of Panicles plot^{-1}
P4= Panicle Length
P5= Panicle weight plant^{-1}
P6= Grain weight Panicle^{-1}
P7= 1000 grains weight

.r1 ... . r15= indirect percent combined contributions of some yield Characters to sorghum grain yield via P2 ......P7

When the direct and combined effects were converted to percent contributions, it was observed that the individual contribution of 36.58%, 32.65%, 13.98%, 3.91% and 1.15% were from number of panicles plot^{-1} , panicle length, panicle weight plant^{-1} , 1000 grains weight, and days to 50% heading respectively (Figure 5). The grain weight panicle^{-1} made the least percent contribution of 0.204%. The highest combined contribution to grain yield ha^{-1} of 57.15% was from the combination of number of panicles plot^{-1} via panicle length while the least was from panicle length via panicle weight plant^{-1} (-34.79%). And the highest total percentage contribution to yield was by number of panicles plot^{-1} (93.73%) from its direct contribution of 36.58% and its indirect contribution with panicle length of 57.159%. The percent unaccounted variability was 7.474%.

Figure 6 shows the direct and combined effects of the yield components to grain yield in the combined years. It was observed that the direct individual percent contribution of 31.93%, 13.12%, 6.40%, 5.35 and 5.33% were from grain weight panicle^{-1}, number of panicles plot^{-1}, panicle weight plant^{-1}, panicle length, and grain weight panicle^{-1} respectively. The combined contribution of grain weight panicle^{-1}and 1000 grains weight made the highest percent combined contribution of 20.79%, while the least combined percent contribution is from panicle weight plant^{-1} via grain weight panicle^{-1} (-21.49%). The total percentage contribution to grain yield of (52.716%) was by grain weight panicle^{-1} from its direct contribution of 31.928% and the indirect contribution of grain weight of panicles^{-1} via 1000 grains weight of 20.79%. The percent unaccounted variability was 40.30%.

DISCUSSION

The significant and positive relationship exhibited between grain yield ha^{-1} and days to 50% heading, number of panicles plot^{-1}, panicle length, panicle weight plant^{-1}, grain weight panicle^{-1}and 1000 grains weight at both locations, years and combined seasons confirmed the interdependence and the yield contributing nature of these plant parameters. The yield components used for the analysis showed that greatest contribution to yield were made through grain weight panicle^{-1}, panicle length, panicle weight plant^{-1} and number of panicles plot^{-1}. Thus, the correlation coefficient and path coefficient has explained the true association between these characters and selection of these variables could improve grain yield of sorghum. The explanation for this could be due the fact that these characters are among the important yield determinants. Similar significant and positive inter-dependence among yield and yield characters such as panicle length, panicle weight plant^{-1} grain weight panicle^{-1} and 1000 grains weight were reported by Ezeaku and Mohammed (2006); Goma *et al*. (2020).

The path coefficient analysis at both locations, years and combined seasons revealed that the highest direct contribution among the yield characters was not consistent among the locations, years and combined seasons. At Samaru, the highest direct contribution was from panicle weight plant^{-1} in 2013 while at Maigana it was number of panicles plot^{-1}. The highest indirect contribution to yield was by panicle length with panicle weight plant^{-1} at Samaru but at Maigana it was number of panicles plot-^{1} with panicle weight plant^{-1}. Panicle length made the highest direct contribution to yield in 2014 at Samaru, but at Maigana it was number of panicles plot^{-1}. However, the indirect contributions of number of panicles plot^{-1} with panicle length were the highest at both locations. The combined seasons reveal that, at Samru, the direct contributions of number of panicles plot^{-1} and the indirect contributions of panicle length with grain weight panicles^{-1} were the highest. However, at Maigana, the direct contributions of grain weight panicle^{-1} and the indirect contributions of grain weight panicles^{-1} with 1000 grains weight were the highest. The highest direct and indirect contributions to yield by the various yield characters, suggest that these characters have the efficiency for accumulation of assimilate and partitioning into yield, being the most important apparatus responsible for assimilating accumulation and partitioning that eventually translated into economic yield of sorghum. These findings corroborated Ezeaku and Mohammed (2006), Iyanar *et al*. (2001), Patil *et al*. (2009) and Umakanth *et al*. (2005).

The residual effect determines how best the causal variables (days to 50% heading, number of panicle plot^{-1}, panicle length, panicle weight plant^{-1}, grain, weight panicle^{-1} and 1000 grains weight) account for the variability of the dependent variables i.e grain yield. It was observed that 7.61%, 8.23% and 12.12% for Samaru; 38.95%, 7.47% and 40.30% for Maigana of the variability remained unaccounted during the two years and combined, respectively. The low residual values obtained at Samaru and in 2014 only at Maigana signifies that the major characters contributing to the grain yield of sorghum were considered.

CONCLUSION

These findings explained that parameters such as panicle weight plant^{-1}, panicle length, grain weight panicle^{-1} and number of panicles plot^{-1} are among the most important determinant of sorghum yield. Therefore, they should be considered when planning a technology that is aiming at improving sorghum yield.

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