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A productive breeding programme on exploitation of heterosis for early vigour and productivity related traits in identified local landraces of *rabi* sorghum [*Sorghum bicolor* (L.) Moench]

Prashant Kariyannanavar, ST Kajjidoni and LK Verma

Abstract
Sorghum is grown under rainy and post rainy (*rabi*) seasons. However, the grain sorghum raised during season has better grain and roti making quality which is preferred by the consumers. However, the yield level of *rabi* sorghum is low due to many factors such as environmental fluctuations, prone to diseases and long duration. At this context landraces will came into breeding rescue which represent heterogeneous, local adaptations of domesticated species, and thereby provide genetic resources that meet current and new challenges for farming in stressful environments. The present study stressed on the exploitation of hybrid vigour for productive related traits by using the landraces which are selected from the minicore collections for physical grain quality parameters, lodging resistance and stay greenness. Interestingly, out of 48 hybrids obtained by crossing 8 lines and 6 testers, 54.17% hybrids are lusturous, SPV-2333 x RSLG-23 is an outstanding hybrid having robust early vigour, superior grain quality, fodder yield and attractive physical grain quality parameters which is further advanced to isolate Trasngressive Seggrants.

Keywords: Landraces, early vigour, heterosis

Introduction
Plant landraces represent heterogeneous, local adaptations of domesticated species, and thereby provide genetic resources that meet current and new challenges for farming in stressful environments. These local ecotypes can show variable phenology and low-to-moderate edible yield, but are often highly nutritious. The main contributions of landraces to plant breeding have been traits for more efficient nutrient uptake and utilization, as well as useful genes for adaptation to stressful environments, grain yield and quality. The Biodiversity Act (2002) describes “landrace” as primitive cultivar that was grown by ancient farmers and their successors. Sorghum germplasm collections in Karnataka represents greater genetic diversity as the crops is being grown traditionally under varied agro climatic conditions in centuries. Most of the landraces are new versions of the past collections with natural crossing and selection and utilization of the accessions over the decades by the farming community. These land races with rare and useful alleles could serve as a potential donar for yield enhancement and also for developing varieties to withstand biotic and abiotic stresses in the semi-arid tropical regions

Early vigor in sorghum is considered an essential component of crop plant development under most environmental conditions (Ludlow and Muchow, 1990) [14]. In arid environments, crop varieties with early seedling vigor and good stand establishment tend to maximize use of available soil water, resistance to shoot fly, resulting in increased dry matter accumulation and improved grain yield. Seedling vigor in sorghum has been assessed by direct measurement of seedling dry weight, which was highly correlated to leaf area, leaf number, and plant height (Maiti *et al.*, 1981) [15] and these characters used in the present study. Plant characteristics that are responsible for differences in early seedling vigor among and within plant species have not been fully explored and present study emphasis on this.

Sorghum is unique to adapt to environmental extremes of abiotic and biotic stress. So this makes the crop to minimize the risk and enables to fit to a sustainable and economically profitable dry land production system. Hybrid vigour and its commercial exploitation have paid rich dividends in *Kharif* sorghum leading to quantum jump in sorghum production. However, the progress in *rabi* sorghum is limited and there is a need for critical studies on combining ability and heterosis involving diverse source of germplasm and land races. Superior grain quality (bold, white and sweeter taste) is found in few sorghum landraces and even today most of the farmers prefer to cultivate landraces of sorghum during *rabi*. In general sorghum landraces have low yields and needs improvement in this direction. Further recent trends in sorghum improvement indicate, need for the exploitation hybrid vigour for increased yield coupled with superior grain quality to meet the demands for *rabi* sorghum. Present study emphasis on introgression of superior alleles from identified local landraces to the newly released varieties of *rabi* sorghum.

Material and Methods

The 64 entries were sown in the randomized block design with two replications, where each entry was sown in single row of 3 m length with inter row spacing of 45 cm and intra row spacing of 15 cm, in vertisol (medium deep black soil) under rain-fed condition at AICRP on Sorghum, University of Agricultural Sciences, Dharwad during *rabi* 2017-18. The recommended Fertilizer dose of 50:25:0 kg/ha of N, P_2O_5, K_2O was applied and agronomic practices were followed to raise crop. From each entry five competitive plants were tagged randomly and numbered for recording observations on early vigour and quantitative characters. Mean of the five plants for each entry was used for analysing line × tester method suggested by Kempthorne (1957) [12]. Seeds for the physical grain quality parameters were classified based on the scale given by Elongovan *et al.*, 2004 [4].

Results and discussion

Heterosis is usually expressed in the form of increased yield which in turn is dependent on the contribution of many component characters. All the component characters of yield were studied for heterosis manifestation in order to assess the worth of a cross. Grain yield is a complex quantitative character influenced by both directly or indirectly by many component traits. Ear head traits *viz.*, panicle length, breadth and weight along with 100 seed weight and early vigour traits *viz.*, root collar diameter, leaf length, leaf width, no of leaves and SPAD values largely governs grain yield in sorghum. The effective landraces are selected for the various traits (Table 1) in order to introgres the desirable genes to the presently cultivating popular variety. In this context results obtained in this study are in the positive directions for the yield and yield attributing traits which are depicted below.

Table 1: List of parents and checks used for combining ability study (L x T) (2017-18 *rabi*)

Lines/Testers		Genotype	Salient features of the genotypes
Lines	L_1	Barsi Jowar	Semi compact panicle and Bold seeded.
	L_2	Billigunda	Stay green, Early, Compact head and Non lodging.
	L_3	Madbhavi Local	Early, Medium head size but susceptible charcoal rot.
	L_4	Kodmurki Local	Semi compact ear head. Beak shaped panicle and Bold seeded.
	L_5	Lakmapur Local	Stay green, Non lodging. Bold seeded and Charcoal rot resistant.
	L_6	SPV-2217	Stay green, Non lodging and Charcoal rot resistant.
	L_7	CSV-216R	Good grain quality along with resistant to shoot fly but susceptible to charcoal rot.
	L_8	SPV-2333	Stay green, Non lodging, Bold seeded and Charcoal rot resistant.
Testers	T_1	EC-8	Compact head, charcoal rot resistant but susceptible to rust
	T_2	IS- 3971	Susceptible to charcoal rot but resistant to rust.
	T_3	IS-4631	Round grains, susceptible to charcoal rot and rust.
	T_4	RSLG-23	Early, good fodder yield, rust resistant and moderately resistant to charcoal rot.
	T_5	EP-83	Lustrous seed, moderately resistant to charcoal rot and rust.
	T_6	EC-15	Lustrous seed, moderately resistant to charcoal rot and rust.
Checks	C_1	M 35-1	Good grain quality but susceptible to charcoal rot.
	C_2	SPV-2217	Stay green. Non lodging. Along with charcoal rot resistant.

All the characters studied in the present investigation exhibited significant better parent heterosis in majority of the crosses indicating predominance of non-additive gene action in the genetic control of these traits. Most of the hybrids expressed significant standard heterosis for 7 traits over the check M 35-1 in desirable direction (Table 2). Early flowering and early maturing genotypes are usually preferred in *rabi* sorghum as they es*cap*e terminal drought avoiding yield loss and reduced grain size due to terminal drought. The cross, Billigunda x IS-4631 (-7.81%) exhibited maximum standard heterosis for days to fifty percent flowering in desired direction and attained fifty percent flowering at 59 days after sowing this knowledge about maturity is essential to decide the adoptability of the genotype to particular soil type depending on soil moisture status (Crook and Cascady 1974) [3].

In case of plant morphological traits (Table 2) it is clear that as many as 36 (leaf breadth) and 34 (leaf length), 5 (SPAD), 2 (number of leaves per plant), 1 (plant height), crosses were significantly heterotic for different morphological traits over standard check. These morphological traits have importance in determining grain as well as fodder yield individually or complementary to one another and all together decides total photosynthetic area of a genotype and reflects the photosynthetic efficiency of the genotype, which intern accounts for total grain yield and biomass (fodder yield) accumulation (Ravindrababu *et al.*, 2001, Alhassan *et al.*, 2008, Jain and Patel 2014 and Khandelwal *et al.*, 2015) [19, 1, 10, 13].

Table 2: Average heterosis and range of heterosis with number of heterotic crosses of parents and F_1s in desirable directions in respect of quantitative traits and early vigour in *rabi* sorghum

Sl. No.	Quantitative Traits	Average heterosis (%)	Range of heterosis (%) over		No. crosses with significant heterosis in desired direction over	
			Better Parent	Standard Check	Better Parent	Standard Check
1	Days to 50% flowering	-0.10	-13.99 – 8.09	-5.47 – 14.84	9	1
2	Days to physiological maturity	0.38	-7.45 – 7.44	-2.08 – 8.33	6	0
3	Plant height (cm)	5.54	-22.96 – 12.26	-17.08 – 23.96	2	10
4	Panicle length (cm)	14.12	-27.73 – 48.73	-22.22 – 38.73	11	18
5	Panicle breadth (cm)	6.72	-23.12 – 27.36	-7.25 – 58.70	8	23
6	Panicle weight (g)	21.26	-46.72 – 58.15	-12.31 – 142.83	15	33
7	Grain yield per plant (g)	39.59	-28.65 – 92.07	-10.62 – 124.38	30	33
8	Fodder yield per plant (g)	6.59	-40.87 – 46.46	-55.10 – 15.65	1	0
9	100 grain weight (g)	1.33	-22.05 – 17.25	-15.35 -22.54	1	13
	Early vigour at 60 days					
10	Root collar diameter	10.25	-25.74 – 37.93	-14.38 – 41.78	8	21
11	Plant height	-0.86	-40.83 – 15.32	-39.57 – 22.90	1	1
12	Number of leaves per plant	-5.48	-26.02 – 13.06	-19.65 – 14.79	1	2
13	Leaf length (cm)	7.92	-13.56 -18.32	-11.81 – 27.31	5	34
14	Leaf breadth (cm)	11.62	-11.45 – 25.07	0.51 – 36.73	20	36
15	SPAD value	4.44	-29.59 – 19.14	-31.41 – 22.71	4	5

Indeed, in sorghum, grain yield and yield attributing traits are hardcore components. As many as 18, 23, 33 and 33 crosses were heterotic over standard check for panicle length, panicle breadth, panicle weight and grain yield per plant respectively. The mean performance of hybrids along with heterosis will serve as useful guide in selecting potential hybrids. It is clear from the study that exploitation of heterosis for grain yield as such would be effective to develop high yielding hybrids and transgressive seggregants, instead of attempting through other yield attributing traits to address yield improvements. The cross, Kodmurkhi Local x RSLG-23 recorded highest grain yield of 98.95 g followed by CSV-216R x IS-4631 (96.50 g), Kodmurkhi Local x EC-8 (91.25 g) and Lakmapur Local x EC-8 (89.28 g) hybrids (Table 3.a and 3.b). However, Kartik (2004) [11], Hovny *et al.* (2001), Mahdy *et al.* (2011) [16], Hariprasanna *et al.* (2012) [7], Prabhakar *et al.* (2013), Thakare *et al.* (2014) [21], Kumar and Chand (2015), Gite *et al.* (2015) [5] also reported high heterosis in the top ranking crosses for grain yield.

Table 3.a: *Per* se performance along with their heterosis and *sca* effects of top ten crosses for grain yield per plant and their component traits in *rabi* sorghum

Sl. No	Top ten crosses for Grain yield per plant (g)	Grain yield per plant (g)				Panicle length (cm)				Panicle breadth				Hundred seed weight			
		Mean	Better parent heterosis (%)	Standard heterosis (%)	*sca* effects	Mean	Better parent heterosis (%)	Standard heterosis (%)	*sca* effects	Mean	Better parent heterosis (%)	Standard heterosis (%)	*sca* effects	Mean	Better parent heterosis (%)	Standard heterosis (%)	*sca* effects
1	Kodmurkhi Local x RSLG-23	98.95	91.02**	124.38**	16.01**	18.65	10.03	18.41**	1.36	8.30	-1.78	20.29**	-0.26	3.58	-9.37*	0.85	-0.12
2	CSV-216R x IS-4631	96.50	87.38**	118.82**	27.32**	20.35	15.30*	29.21**	1.03	8.35	10.60	21.01**	0.32	3.93	1.82	10.56*	0.39**
3	Kodmurkhi Local x EC-8	91.25	77.53**	106.92**	3.19	18.90	-5.74	20.00**	-0.25	10.95	26.59**	58.70**	1.85**	3.50	-6.54	-1.41	-0.07
4	Lakmapur Local x EC-8	89.28	56.90**	102.44**	19.59**	19.15	-4.49	21.59**	1.03	9.10	5.20	31.88**	1.22**	4.01	-5.09	12.82*	0.25
5	SPV-2333 x RSLG-23	88.80	71.43**	101.36**	21.16**	18.10	6.78	14.92*	1.25	8.65	2.37	25.36**	1.09**	4.07	0.49	14.79*	0.32*
6	SPV-2217 x RSLG-23	83.30	-28.65*	-7.94	17.17**	18.20	7.37	15.56*	0.43	7.95	-5.92	15.22*	0.88**	3.96	60.81**	88.89**	0.11
7	CSV-216R x EP-83	83.00	-11.59	2.04	17.00**	19.50	10.48	23.81**	0.44	8.42	11.46	21.96**	0.51	3.63	-5.84	2.25	-0.03
8	Barsi Jowar x RSLG-23	82.10	57.28**	86.17**	18.19**	18.70	10.32	18.73**	1.41	8.15	-3.55	18.12**	0.47	4.03	-0.49	13.52**	0.37**
9	SPV-2217 x EC-8	82.06	59.65**	86.0**	10.81*	20.00	-0.25	26.98**	0.38	6.91	-20.17**	0.07	-0.70*	4.04	3.73	13.66**	0.33**
10	Madbhavi Local x EC-8	79.05	53.79**	79.25**	0.80	19.10	-4.74	21.27**	1.10	8.15	-5.78	18.12**	-0.08	3.71	-1.07	4.37	0.03

Table 3.b: *Per* se performance along with their heterosis and *sca* effects of top ten crosses for grain yield per plant and their corresponding early vigour traits in *rabi* sorghum

Sl. No	Top ten crosses for Grain yield per plant (g)	Grain yield per plant (g)				Root collar diameter (cm)				Leaf length (cm)				Leaf breadth (cm)			
		Mean	Better parent heterosis (%)	Standard heterosis (%)	*sca* effects	Mean	Better parent heterosis (%)	Standard heterosis (%)	*sca* effects	Mean	Better parent heterosis (%)	Standard heterosis (%)	*sca* effects	Mean	Better parent heterosis (%)	Standard heterosis (%)	*sca* effects
1	Kodmurkhi Local x RSLG-23	98.95	91.02**	124.38**	16.01**	1.84	8.24	26.03*	0.10	61.35	2.42	13.19	-0.54	8.53	12.83**	23.36**	0.43
2	CSV-216R x IS-4631	96.50	87.38**	118.82**	27.32**	2.07	37.09**	41.78**	0.23*	62.45	8.04	15.22*	2.02	9.02	19.47**	30.44**	0.50*
3	Kodmurkhi Local x EC-8	91.25	77.53**	106.92**	3.19	1.81	6.18	23.63*	18.17	64.50	2.06	19.00**	1.79	8.75	5.42	26.54**	0.58*
4	Lakmapur Local x EC-8	89.28	56.90**	102.44**	19.59**	1.86	9.76	27.05**	0.20*	62.30	-1.42	14.94*	-3.87	8.49	2.23	22.70**	0.17
5	SPV-2333 x RSLG-23	88.80	71.43**	101.36**	21.16**	2.02	20.66*	38.01**	0.19	63.30	3.60	16.79*	-2.05	9.46	25.07**	36.73**	0.38
6	SPV-2217 x RSLG-23	83.30	-28.65*	-7.94	17.17**	1.79	7.19	22.60*	0.22*	59.10	-1.34	9.04	-3.16	7.85	3.84	13.52**	-0.35
7	CSV-216R x EP-83	83.00	-11.59	2.04	17.00**	2.02	33.44**	38.01**	0.08	58.30	-5.20	7.56	0.31	8.60	4.88	24.37**	-0.16
8	Barsi Jowar x RSLG-23	82.10	57.28**	86.17**	18.19**	1.55	-7.19	6.16	0.09	64.50	5.22	19.00**	1.41	8.84	10.44**	27.77**	0.86**
9	SPV-2217 x EC-8	82.06	59.65**	86.0**	10.81*	1.26	-25.74**	-14.04	-0.26**	64.50	2.06	19.00**	1.42	8.55	3.01	23.64**	0.28
10	Madbhavi Local x EC-8	79.05	53.79**	79.25**	0.80	1.69	0.00	15.75	0.05	63.45	0.40	17.07*	-0.11	8.35	0.54	20.68**	0.37

In the present study higher magnitude of average heterosis (6.59%) with wide range of standard (-55.10 to 15.65%) and better parent (-40.87 to 46.46%) heterosis was observed for fodder yield per plant. In general selection and identification of productive hybrid may not be based on expression of heterosis over better parent and standard check, but it is essential to consider the mean performance along with heterosis value were reported by Ravindrababu and Pathak (2000), Jahagirdar and Borikar (2004) [9], Rajguru *et al.* (2005) [20], Patil and Biradar (2005) [17], Ghorade *et al.* (2007) [6], Kumar and Chand (2015). The crosses, SPV-2333 x RSLG-23 and Barsi Jowar x EC-15 were good for grain yield of 88.8 g and 73.5 g with 101.36% and 67.35% standard heterosis respectively for grain yield per plant (Table 3.c). From the present study it is clearly indicated that the possibility of exploitation of heterosis for fodder as well as grain yield per plant to develop dual purpose cultivars in *rabi* sorghum genotypes.

Table 3.c: *Per* se performance along with their heterosis and *sca* effects of top ten crosses for grain yield per plant and their corresponding fodder yield per plant, physical grain quality parameters in *rabi* sorghum

Sl. No	Top ten crosses for grain yield per plant (g)	Grain yield per plant (g)				Fodder yield per plant (cm)				Physical Grain quality		
		Mean	Better parent heterosis (%)	Standard heterosis (%)	*sca* effects	Mean	Better parent heterosis (%)	Standard heterosis (%)	*sca* effects	Seed shape	Seed color	Seed Lusture
1	Kodmurkhi Local x RSLG-23	98.95	91.02**	124.38**	16.01**	155.00	-20.31	5.44	23.14	R	LY	L
2	CSV-216R x IS-4631	96.50	87.38**	118.82**	27.32**	162.50	8.33	10.54	19.78	R	CS	L
3	Kodmurkhi Local x EC-8	91.25	77.53**	106.92**	3.19	145.00	46.46*	-1.36	9.01	O	CS	I
4	Lakmapur Local x EC-8	89.28	56.90**	102.44**	19.59**	118.00	-25.55	-19.73	6.01	R	LY	I
5	SPV-2333 x RSLG-23	88.80	71.43**	101.36**	21.16**	165.5	-14.91	12.59	29.80*	R	LY	I
6	SPV-2217 x RSLG-23	83.30	-28.65*	-7.94	17.17**	127.00	-34.70**	-13.61	-10.20	R	CS	I
7	CSV-216R x EP-83	83.00	-11.59	2.04	17.00**	146.50	-9.85	-0.34	1.97	R	LY	L
8	Barsi Jowar x RSLG-23	82.10	57.28**	86.17**	18.19**	155.00	-20.31	5.44	10.14	R	CS	L
9	SPV-2217 x EC-8	82.06	59.65**	86.0**	10.81*	135.00	-20.82	-8.16	-6.32	R	LY	L
10	Madbhavi Local x EC-8	79.05	53.79**	79.25**	0.80	86.50	-40.34**	-41.16**	-38.24*	R	LY	L

R = Round.
O = Oval.
CS = Chalky straw.
LY = Light yellow. .
L = Lustrous.

Interestingly, 54.17% of the total hybrids obtained were Lusturous, 54.14 were round, and 43.75% were creamy straw and these traits which consumers usually prefer. Finally, SPV-2333 x RSLG-23 is an excellent outcome having superior grain quality, fodder yield and attractive physical grain quality parameters which can be further advanced to isolate Trasngressive Seggrants.

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