Indian J. Plant Genet. Resour. 32(2): 125-134 (2019)
DOI 10.5958/0976-1926.2019.00016.0

RESEARCH ARTICLE

Expression and Stability Studies on Axillary Branching in Novel Grain Sorghum (*Sorghum bicolor* L.) Somaclonal Mutant, SbABM

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(Received: 01 March 2017; Revised: 05 April 2018; Accepted: 09 April 2018)

Sorghum bicolor axillary branched mutant (SbABM) is the first axillary branched mutant reported in grain sorghum till date with desirable phenotype and stability of expression of axillary branching over generations. However, the trait was expressed at different levels of intensity (for number of axillary branches per plant) within the progenies of a single true breeding plant. The mutant along with its parent A-1 and a local check M 35-1 were analysed in variable environments like variation in plant density and intensive management practices over years to understand the stability and expression of axillary branching. The mutant exhibited significant increase in yield which was in turn attributed to significant increase in yield attributing parameters *viz.,* number of branches per plant, number of panicles per plant, panicle weight per plant and thousand seed weight compared to A-1 and M 35-1 in all the three spacings and at two fertilizer levels. However, the expression of the traits in SbABM under different treatments was at par with each other. Though there was some variation in the degree of expression of characters in SbABM, the expression of the characters was highly stable, genetically controlled and significantly superior over the other two *rabi* varieties.

Key Words: Axillary branching, Lodging resistance, Mutant, Stay green, Variable environment

Introduction

Shoot architecture is largely determined by the number of axillary shoots produced. Axillary shoot development begins with the initiation of a meristem in the axil of a leaf to form a bud (Ward and Leyser, 2004; McSteen and Leyser, 2005). Depending on internal and environmental signals, the bud may continue growing to form an axillary shoot or enter into dormancy. In this context, axillary branching has great relevance to modern agriculture by maintaining an appropriate branching habit that maximizes utilization of resources and production of biomass and/or reproductive structures. This goal may be achieved in part through a better understanding of mechanism of axillary shoot development in plants. In-depth knowledge of the development of branches will help in modifying the shoot architecture of crops to maximize yield. Although environmental signals are key determinants of the development of an axillary shoot, little has been done to understand how these signals regulate branching at the molecular level.

To examine axillary shoot development in plants, axillary meristem mutants have been identified and characterized in maize, pea, petunia, tomato and *Arabidopsis* (Kerstetter and Hake, 1997; Schmitz and Theres, 1999). There are no detailed studies in sorghum except those on the wild type sorghum with axillary branching and its mutant phyB-1 (phytochrome B) by Kebrom *et al.* (2006). Grain sorghum (*Sorghum bicolor* L.) is an important source of food, feed and biofuel, especially in the semi-arid tropics because this cereal is well adapted to harsh, drought prone environments. The cultivated sorghum genotypes are generally uniculm. However, Maralappanavar *et al.* (2000) reported an axillary branched mutant, SbABM (*Sorghum bicolor* Axillary Branched Mutant) in cultivated sorghum obtained through somaclonal mutation, derived from Annigeri-1 (A-1) wherein branching at every node from the lower most node till the top most, was reported (Fig. 1). This is the first axillary branched mutant reported in grain sorghum till date with desirable phenotype and stability of expression over generations. Sorghum is a self- pollinated species and the axillary branched mutant plants were maintained as homozygous, true breeding lines for several generations at Agricultural Research

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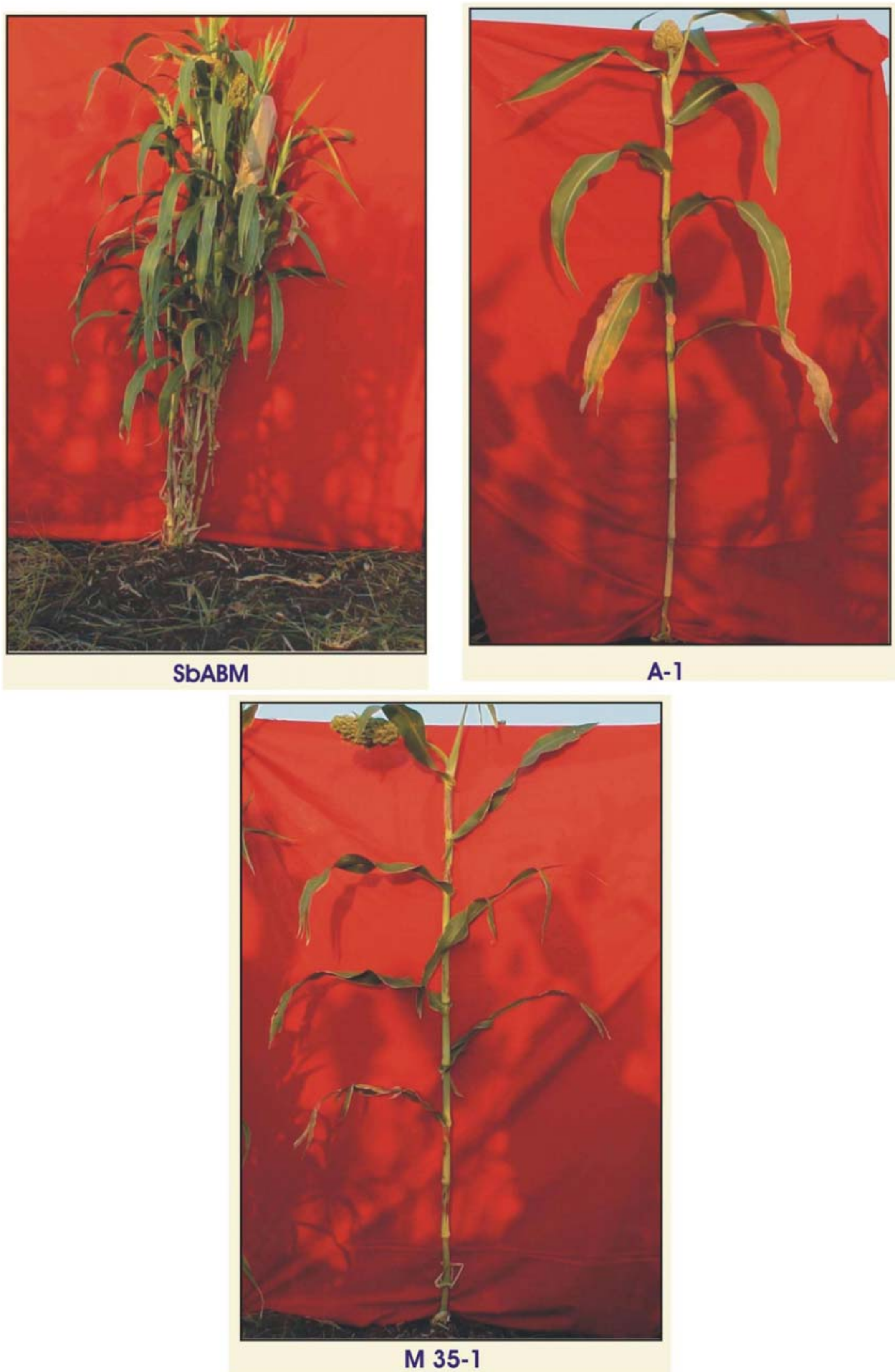

Fig. 1. Phenotypic features of the sorghum mutant, SbABM, parental variety A-1 and the local check M 35-1

Station, University of Agricultural Sciences, Dharwad, India. To understand whether axillary branching in the mutant is genetically controlled or is mainly because of environmental factors, the present study was undertaken to elucidate the stability and expression of axillary branching in variable environments.

Materials and Methods

The experiments on *Sorghum bicolor* were conducted in the experimental field of Agricultural Research Station, University of Agricultural Sciences, Dharwad, Karnataka, India. The experimental site is situated at an altitude of 678 m above the mean sea level at latitude 15°26′ North and at longitude 76°7′ East and has well-drained fertile medium black soil with an average annual rainfall of 735 mm.

The experiment was laid out in a split plot design with three genotypes *viz.*, Annigeri-1 (A-1), SbABM (an axillary branched mutant derived through somaclonal mutation) and a local check M 35-1 (Fig. 1) as main plots, three planting geometries *viz.,* 45 × 15 cm, 60 × 15 cm and 75 × 15 cm as subplots, two fertilizer levels *viz.* 40:20:20 Kg N, P_2O_5, K_2O ha^{-1} and 80:40:40 Kg N, P_2O_5, K_2O ha^{-1} and one protective irrigation at flowering stage *i.e.,* 65 days after sowing as sub subplots with four rows per treatment replicated two times. The same set of experiment was repeated for two years during *rabi* season of 2008-09 and 2009-10.

Fertilizer dose as per the treatments was applied at the time of sowing. Nitrogen, phosphorous and potassium were applied in the form of urea, single super phosphate and nitrate of potash, respectively. Half the dose of nitrogen and, full dose of phosphorus and potassium were applied as basal dose in five cm deep furrows which were opened at five cm away from seed row. The remaining half of nitrogen was top-dressed at 30 days after sowing.

Observations were recorded on ten quantitative traits, *viz.* days to 50% flowering, days to maturity, plant height, number of axillary branches per plant, number of panicles per plant, panicle weight per plant, thousand-grain weight, grain yield per plant, fodder yield per plant and lodging percentage, which are the characteristic idiotypic changes due to somaclonal mutation. Data were recorded on each of the five randomly selected competitive plants tagged in each replication of all the test genotypes.

SPAD Chlorophyll Meter Reading (SCMR)

SPAD (Soil Plant Analytical Development) chlorophyll meter reading (SPAD 502; Minolta company Ltd.) measures the greenness or relative chlorophyll content of leaves. SCMR was taken at an interval of 60 and 90 days after sowing on five random plants. The third leaf from the top was used for measuring SCMR, which was taken on one side of leaf blade, midway between the leaf base and tip. The readings were taken between 10.00 and 12.00 hours of the day. Mean of the readings from five tagged plants was recorded.

The data collected from the experiment were subjected to factorial statistical analysis by Gomez and Gomez (1984). The level of significance in ‘F’ and ‘t’ tests was P = 0.01. Critical difference values were calculated. Treatment combinations were compared by using the critical difference values. Correlation analysis was carried out to study the nature and degree of relationship between various growth yield components and yield. The statistical analyses was worked out individually for both the years.

Results and Discussion

Multiple shoot branching refers to the ability of a plant to produce an extra number of axillary shoots. This phenotype usually reflects healthy and yield-promising plant because increase in shoot branching can be translated to greater vegetative biomass, fruit and seed production. Historically, multiple shoot branches was a desirable trait in some crop plants, such as rice, in which multiple shoot branches (tillers) are associated with increased yield. In contrast, maize cultivars have been selected for a low number of axillary branches to improve the quality of the ears and kernels by concentrating plant resources.

High-yield production can be achieved by genetically altering the number of shoots per plant and/or by modifying other processes related to plant growth and development, as axillary branch formation is controlled by a complex interaction between genetically regulated developmental processes and the environment. Multiple shoot branching can also be achieved, to some extent, by augmenting the amount of fertilizers used in the field. However, the application of large amount of fertilizer to increase the number of shoot branches per plant would not only enhance input cost to farmers, but also lead to an accumulation of unused fertilizers in the soil which would ultimately pollute the groundwater. Therefore, the probable solution is to use reasonable amount of supplied nutrition and genetically alter the number of shoot branches to maximize yield in crop plants. This requires an understanding of the mechanism controlling plant architecture.

Performance of Sorghum bicolor Axillary Branched Mutant SbABM

Genotypes play an important role in determining the yield of a crop. The potential yield of genotypes within genetic limits is set by its environment. Genotypes differ in their yield potential depending on many physiological processes which are controlled by both genetic makeup and the environment.

The performance (for two years) of the three genotypes for grain yield per plant and other related traits is depicted in Table 1 and the average performance over two years is depicted in Figure 2. Of the three genotypes (SbABM, A-1 and M 35-1), SbABM recorded significantly higher grain yield than A-1 and M 35-1 which exhibited comparable yield. The increase in grain yield in SbABM over its parent, A-1 and M -35-1, was 57 and 60.6 %, respectively.

The higher grain yield of SbABM over other two genotypes is attributed to improved yield components like number of branches per plant, number of panicles per plant, panicle weight and thousand grain weight. Axillary branching, the characteristic feature of the mutant, was significantly higher than that in A-1 and M 35-1. The average number of branches per plant in the mutant was 7.78 compared to 2.33 in A-1 and 2.12 in M 35-1. The increase in number of branches per plant also resulted in significant increase in fodder yield per plant (109.46 gm) in the mutant. Out of eight branches

Table 1. Expression of different traits in three sorghum genotypes as influenced by different row spacing and fertilizer levels

Treatments	Days to 50% flowering		Days to maturity		Plant height (cm)		Number of axillary branches per plant		Number of panicles per plant	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Genotypes										
A-1	76.8	73.2	135.5	129.5	181.25	174.26	2.41	2.25	1.83	1.83
SbABM	65.0	68.9	149.6	145.1	166.61	164.28	7.66	7.91	5.00	6.08
M35-1	75.8	70.2	134.3	126.8	190.92	152.46	2.25	2.00	1.66	1.67
S.Em ±	0.8	0.9	2.0	1.9	3.40	3.35	0.98	0.74	0.98	0.74
CD (P=0.01)	3.6	3.8	9.5	8.8	14.70	14.47	4.23	3.20	4.23	3.20
Spacing										
45 x 15 cm	72.8	71.9	137.5	126.3	185.45	174.27	3.66	3.25	2.16	2.33
60 x 15 cm	73.4	72.9	139.1	132.2	187.99	164.29	4.16	4.33	2.83	3.41
75 x 15 cm	74.2	72.2	142.9	133.3	165.37	152.46	4.50	4.58	3.50	3.83
S.Em ±	0.9	0.7	1.6	0.3	2.33	3.78	1.12	0.98	0.22	0.23
CD (P=0.01)	5.6	NS	10.2	NS	15.19	24.58	7.29	6.38	NS	NS
Fertilizer (Kg NPK/ha)										
40:20:20	73.4	71.3	138.5	133.8	170.29	151.20	3.77	3.66	2.50	2.83
80:40:40	73.6	73.3	141.2	127.3	188.90	176.13	4.44	4.44	3.16	3.55
S.Em ±	0.4	0.3	1.2	0.2	14.57	2.49	0.54	0.35	0.24	0.04
CD (P=0.01)	31.8	NS	106.1	NS	311.42	223.89	NS	NS	NS	NS

NS- Not significant

Contd.

Treatments	Panicle weight per plant (g)		Thousand grain weight (g)		Grain yield per plant (g)		Fodder yield per plant (g)		Lodging percentage	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Genotypes										
A-1	64.29	57.91	30.27	30.95	55.10	44.12	61.90	67.07	83.66	80.58
SbABM	96.30	83.33	36.77	35.91	85.67	75.58	102.54	116.38	26.00	34.08
M35-1	65.09	64.75	31.60	30.95	51.92	47.97	58.78	69.43	83.83	79.66
S.Em ±	4.45	1.68	0.74	0.82	3.00	1.96	1.20	1.55	1.03	1.09
CD (P=0.01)	19.22	7.27	3.11	3.54	12.97	8.47	5.19	6.71	4.47	4.71
Spacing										
45 × 15 cm	75.63	67.09	32.30	32.97	64.31	51.41	73.70	77.37	62.74	68.41
60 × 15 cm	74.12	68.64	33.14	32.08	66.56	52.71	72.77	87.31	65.41	62.00
75 × 15 cm	75.93	7078	33.20	32.84	69.97	55.19	76.75	88.21	65.33	63.91
S.Em ±	2.61	3.74	0.37	NS	2.87	0.75	1.04	2.09	2.03	0.79
CD (P=0.01)	16.99	24.35	0.12	NS	18.68	4.88	6.79	13.62	13.19	5.14
Fertilizer (Kg NPK/ha)										
40:20:20	73.64	65.82	33.05	33.14	64.45	53.53	68.25	85.04	63.94	58.88
80:40:40	76.81	71.84	32.72	32.07	64.01	58.24	80.56	83.55	65.05	70.66
S.Em ±	3.80	0.71	0.26	NS	0.76	0.10	0.83	1.65	0.79	0.71
CD (P=0.01)	341.69	63.87	0.34	NS	68.04	10.86	74.45	148.25	70.73	63.66

NS- Not significant

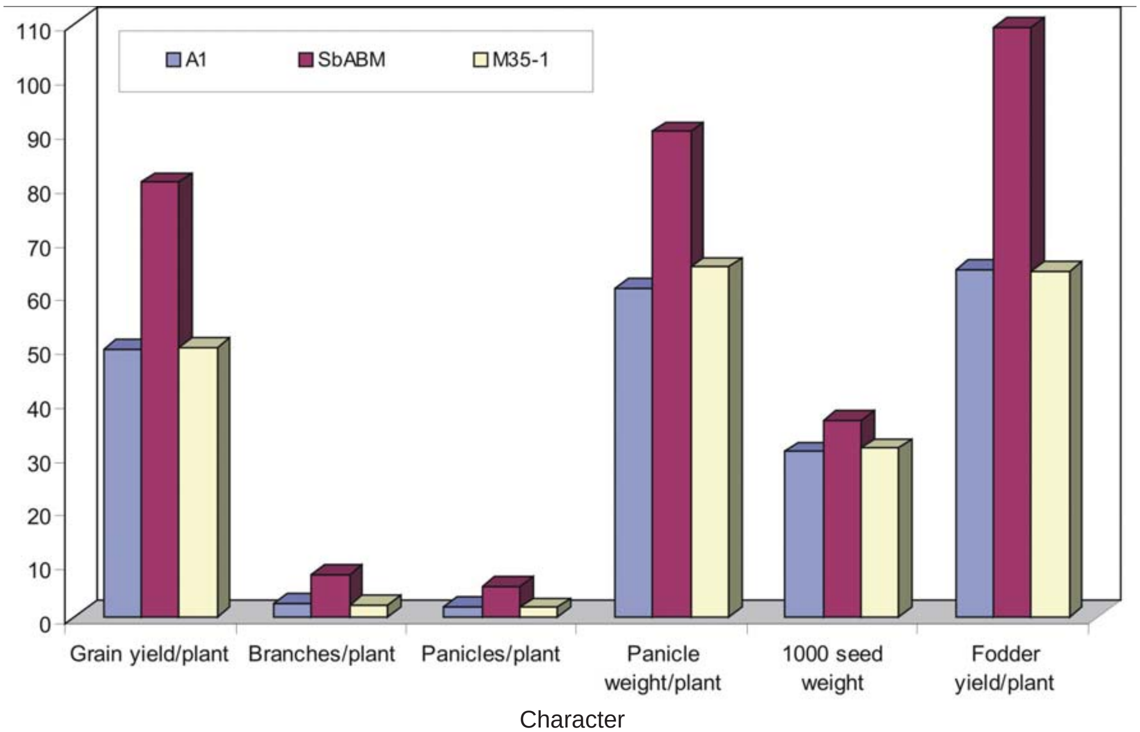

Fig. 2. Average performance of the three sorghum genotypes for important yield characters

per plant, six branches produced fertile inflorescence in SbABM as against 1.83 and 1.66 in A-1 and M 35-1, respectively.

The increase in number of panicles per plant resulted in increased panicle weight of the mutant. The panicle weight/plant in the mutant was 41.21 and 52.94% higher than that in A-1 and M 35-1, respectively. Similarly, per cent increase in thousand seed weight in the mutant compared to its parent and local check was 16.1 and 18.7 %, respectively. The grain size in all the lateral branches was same as in the main head. Owing to this positive feature, it is possible to bulk the seeds from main as well as axillary heads without discriminating between them.

The mutant SbABM, not only exhibited improved yield, but also displayed improvement in some of the growth components. Significant difference was observed between the genotypes for days to 50 % flowering. The mutant took significantly less number of days and flowered 8.25 and 9.79 days earlier than did A-1 and M 35-1, respectively. The mutant displayed reduced plant height compared to that of A-1 and M 35-1. Average plant height of the mutant was 165.44 cm whereas that of A-1 and M 35-1 was 177.73 cm and 171.69 cm, respectively.

There was 63% more lodging in A-1 and M 35-1 compared to that in the mutant (Fig. 3). On an average, only 30% of the plants showed lodging in SbABM, whereas in A-1 and M 35-1, 80 % of the plants showed lodging at the time of harvest. Usually dryness of the stalk is associated with lodging of the plant. In this mutant, at every node, new growth was induced which was similar to the growth in main stem. By virtue of this, the branches as well as the main stem remain juicy. It is because of this reason that the mutant resists lodging.

Leaf greenness, an integrated measure of the stay green phenotype, was analyzed using SPAD meter at 60 and 90 days after sowing (Table 2). The average SPAD values recorded at 90 DAS was less compared to the values recorded at 60 DAS in all the three genotypes At 60 DAS, there was 43.7 and 38.7 % more leaf greenness in the mutant than that in A-1 and M 35-1, respectively. Similarly, the per cent increase at 90 DAS was 58.25 and 54.48 in the mutant compared to that at, in A-1 and M 35-1, respectively. This clearly shows that, when the two genotypes, A-1 and M 35-1 exhibited senescence, the mutant still showed leaf greenness. The SPAD readings clearly indicated increased chlorophyll content in the mutant. This is an indication of additional greenness at different stages of crop growth. Even after maturity, the

Fig. 3. Plant type features of sorghum mutant, SbABM

Table 2. SPAD chlorophyll meter reading in three sorghum genotypes as influenced by different row spacings and fertilizer levels

Treatments	SPAD chlorophyll meter reading			
	2008-09		2009-10	
	60 DAS	90 DAS	60 DAS	90 DAS
Genotypes				
A-1	30.40	22.56	28.10	21.25
SbABM	43.19	35.33	40.89	34.00
M35-1	31.42	23.65	29.20	22.42
S.Em ±	0.85	0.72	0.77	0.81
CD (P=0.01)	3.67	3.11	3.33	3.50
Spacing				
45 × 15 cm	34.42	26.75	32.12	25.16
60 × 15 cm	34.69	26.55	32.39	25.64
75 × 15 cm	35.90	28.25	33.69	26.86
S.Em ±	0.52	0.47	0.53	0.49
CD (P=0.01)	NS	NS	NS	NS
Fertliser				
40:20:20: Kg NPK/ha	34.51	26.33	32.10	25.44
80:40:40 Kg NPK/ha	35.50	28.03	33.37	26.33
S.Em ±	0.24	0.20	0.24	0.25
CD (P=0.01)	NS	NS	NS	NS

leaves remained lush green pointing to the stay green nature of the genotype. Increased chlorophyll content coupled with stay green nature has led to distinct increase in total photosynthetic output of the leaf. In addition to this, there was a continuous increase in leaf number, contributing to a total increase in green leaf area, finally leading to enhanced source. This, in turn, facilitated increased filling of grains contributing to higher grain weight. Apart from this, the increase in source even in later formed axillary panicles was so evident that the boldness of the grain size was maintained in all the panicles.

The total biomass of SbABM was significantly higher than that of the parent A-1 and M 35-1, contributing to higher fodder value (109.46 g/plant). This is an important requirement for acceptance of *rabi* genotypes.

Effect of Spacing on Genotype

Branching of plants could be modified by altering the plant density. Higher the plant density, lesser is the branching due to increased competition among the plants for light and nutrients. However, lower plant density increases branching of plants. To know the effect of plant density on axillary branching, the mutant along with its parent A-1 and local check M 35-1 were analyzed in three different row spacings.

From Table 1, it is clear that in wider row spacing of 75 × 15 cm, there was increase in yield (83.12 g/plant) of the mutant, SbABM whereas grain yield per plant in closer and medium row spacing was comparable with each other. Compared to A-1 and M 35-1, the mutant displayed significantly higher grain yield in all the three spacings. Average percent increase in grain yield of the mutant was more than 60 compared to that in, of, A-1 and M 35-1, in all the three spacings.

The increased grain yield of the mutant was due to improved yield attributing characters like number of panicles per plant, panicle weight and thousand seed weight exhibited by the mutant. For all the above traits, there were higher values in wider row spacing, though these were at par with closer and medium row spacing.

The mutant exhibited earliness for days to 50% flowering. Among the three spacings, wider row spacing delayed flowering compared to medium and closer row spacing in all the three genotypes. The mutant was 10 days earlier than A-1 and M 35-1 for days to 50 % flowering. This trend was, however, not exhibited for days to maturity. Maturity period of the mutant was delayed by more than 15 days compared to A-1 and M 35-1 in all the three spacings. Closer spacing led to early maturity compared to medium and wider row spacing. Under wider row spacing, the mutant recorded more number of panicles per plant (Table 1) and hence delay in maturity. The mutant produced branches only after the main inflorescence was formed. It took more than a week's time to have inflorescence in the branches, hence increased number of panicles per plant led to the corresponding delay in maturity of the mutant.

Compared to A-1 and M 35-1, the mutant displayed reduced plant height in all the three spacings. Among the three different spacings, the plant height was more in narrow row spacing compared to medium and wider spacing. The increase in plant height under narrow row spacing was mainly due to competition for light among the plants owing to increased plant density.

Number of branches per plant in medium and wider row spacing was significantly higher than that in narrow row spacing in the mutant, SbABM. In the genotypes A-1 and M 35-1, number of branches per plant was comparable among all the three spacings yet it was significantly lower than those of the mutant. On an average, the mutant recorded eight branches per plant. Out of these eight branches, approximately five branches per plant produced panicles. Similar to number of branches per plant, number of panicles per plant was also high in medium and wider row spacing, which were at par with each other and was significantly higher than A-1 and M 35-1 in all the three spacings.

On an average, the mutant exhibited 40% increased panicle weight/plant in all the three spacings compared to its parent and the local check. No significant difference was observed in SbABM for panicle weight among all the three spacings. The mutant recorded significantly higher seed weight (>36.00 g/1000 seeds) irrespective of the spacings, compared to A-1 and M 35-1.

Similarly, the lodging percentage was significantly less (<30%) in the mutant than that in A-1 and M 35-1, in all the three spacing. The resistance to lodging in the mutant could be mainly due to juicy stem. Resistance to lodging is also one of the important traits for terminal drought-tolerant genotypes.

The increase in number of branches per plant also resulted in significant increase in fodder yield per plant (> 100 gm/plant), in the mutant.

The increase in number of leaves per plant increases the photosynthetic area and hence increase in leaf chlorophyll content. As evident from the SPAD meter reading (Table 2), the mutant exhibited significantly higher SPAD meter values than those exhibited by A-1 and M 35-1, at both 60 (>40.00) and 90 (>30.00) days after sowing, in all the three spacings. These traits are very important due to stay green nature of the genotypes and coupled with increased fodder yield and superior quality, make the genotype highly suitable for both grain and fodder purposes.

Effect of Fertilizer and Irrigation on Genotype

Similar to the effect of spacing on genotypes, with the increase in fertilizer and irrigation, the genotypes displayed improved yield and other yield attributing traits. With the increase in fertilizer, the mutant displayed significantly higher yield and yield attributing traits like number of panicles per plant (>5), panicle weight (>90 g/plant) and thousand seed weight (>36 g) when compared with A-1 and M 35-1. Significant difference was also observed for number of branches per plant, fodder yield per plant and SPAD meter readings. Though the mutant was far superior than other two genotypes for most of the agronomic traits, yet it did not exhibit any significant difference at low and high fertilizer levels.

Correlation Analysis

The nature of relationship between grain yield per plant and other parameters was compared with correlation coefficient (Table 3). Grain yield was positively and significantly correlated with all the parameters except for plant height during 2008-09 and 2009-10.

In the mutant (SbABM), axillary branching was seen at nodal points, therefore, the branches were borne on the main stem in an alternate fashion *i.e.,* on left and right side of the main stem. On an average, it was observed that six branches terminated in fertile inflorescence under normal conditions in this genotype. Figure 4 depicts the average % contribution of seed yield from the panicles born on axillary branches on both left and right side of the plant, to the total seed yield per plant. When the distribution of seed weight contributed by each of the side branches was considered, there was a decline in the contribution from side branches which were away from the main branch. Thus, there was a symmetric increase in contribution while moving from last side branch to the main branch. This is one of the characteristic features of the mutant SbABM.

An attempt was made to know the average contribution from main panicle and panicles from axillary branches to the total seed yield per plant in different treatments (three genotypes, three different spacings and two fertilizer levels) (Table 4). From the Table, it is clear that in the mutant, the contribution from main panicle accounts for 40-50 %, whereas that from the panicles of axillary branches was 50-60 % to the total seed yield per plant. In A-1 and M 35-1 genotypes, the

Table 3. Correlation co-efficient (r) between grain yield per plant and other parameters of sorghum

S.No.	Parameters	'r' values	
		2008-09	2009-10
1	Days to 50 percent flowering	0.685*	0.826*
2	Days to maturity	0.820*	0.896*
3	Plant height	0.055	-0.494
4	Number of branches per plant	0.905*	0.953*
5	Number of productive branches per plant	0.913*	0.902*
6	Percentage of branched plants	0.875*	0.926*
7	Number of leaves per plant	0.818*	0.826*
8	Panicle length	0.554	0.880*
9	Panicle breadth	-0.504	-0.667*
10	Panicle weight/plant	0.782*	0.903*
11	Thousand grain weight	0.801*	0.877*
12	Fodder yield per plant	0.859*	0.821*
13	Lodging percentage	0.748*	0.961*

* - Significant at 5% probability level

main panicle contributed more than 70%, while those from axillary branches contributed less than 30 % to the total seed yield per plant.

When the number of branches per plant increased (in wider row spacing and with higher fertilizer dosage), percent contribution from the main panicle to the total yield decreased slightly, while the contribution from the panicles born on axillary branches increased. However, it was seen that in treatments with higher number of branches (wider spacing and higher fertilizer) actual yield per plant was more than that in treatments with lower number of branches (narrow spacing and low fertilizer). Therefore, it can be concluded that, the plant tries to put forth more branches and this trait is enhanced if the plant is given wider spacing or high dose of fertilizer and irrigation (intensive management). From Table 4, it is clear that the % contribution of main panicles became lesser with widening of spacing and higher dose of fertilizer, whereas that from branched panicles increased.

These results *i.e.*, the effect of plant density and increased nutrient supply to the mutant suggested that, even though medium and wider row spacing and increased fertilizer application resulted in the increased expression of different agronomic traits in the mutant, it did not affect the characters studied under different environmental conditions. Therefore, it could be concluded that, even though plastic in nature due to environmental conditions, the mutant characters are genetically controlled and significantly superior to those of the other two *rabi* varieties. A study was also conducted to understand penetrance and expressivity of axillary branching in the mutant and it revealed stable penetrance of more than 85 % for axillary branching (Immadi *et al*., 2014). However, the trait exhibited variable expressivity and the deviation (from mean) among the plants was not heritable. An attempt was also made to understand the nature of inheritance of axillary branching which is of great significance for the genetic modification of plant architecture for improved yield and fodder qualities. The mutant line, SbABM, was crossed with five normal sorghum cultivars both as a male and a female parent, to elucidate the effect of cytoplasm on axillary branching, if any. All the ten F_2 populations showed the same segregation ratio of three mutant to one normal type phenotype based on Chi square test. The results revealed that axillary branching is controlled by a single dominant nuclear gene (Immadi *et al*., 2014).

Considering its developmental significance and phenotypic diversity, this mutant was subjected to detailed genetic analysis (Immadi *et al*., 2016). To

Table 4. Contribution from main panicle and panicles from axillary branches to the total seed yield per plant in different treatments

	Contribution from	45 × 15cm		60 × 15 cm		75 × 15 cm		Low fertilizer		High fertilizer	
		Actual yield (g)	% contribution	Actual yield (g)	% contribution	Actual yield (g)	% contribution	Actual yield (g)	% contribution	Actual yield (g)	% contribution
SbABM	Main panicle	38.35	48.31	36.52	46.06	34.49	41.45	42.34	53.64	38.68	46.99
	Branched panicle	41.04	51.70	42.76	53.94	48.72	58.55	36.59	46.36	43.64	53.01
	Number of panicles	4.13		5.75		6.75		4.92		6.16	
A-1	Main panicle	40.66	79.37	33.58	69.42	38.46	78.11	36.12	71.30	30.25	62.29
	Branched panicle	10.57	20.63	14.79	30.58	10.78	21.89	14.54	28.70	18.31	37.71
	Number of panicles	1.25		2.00		2.25		1.75		1.92	
M 35-1	Main panicle	36.24	75.52	33.58	68.48	37.62	71.22	47.38	100.00	35.29	67.21
	Branched panicle	11.75	24.48	15.45	31.51	15.20	28.78	-	-	17.22	32.79
	Number of panicles	1.38		1.63		2.00		1.33		2.00	

Low fertilizer – 40:20:20 kg NPK/ha High fertilizer – 80:40:40 kg NPK/ha

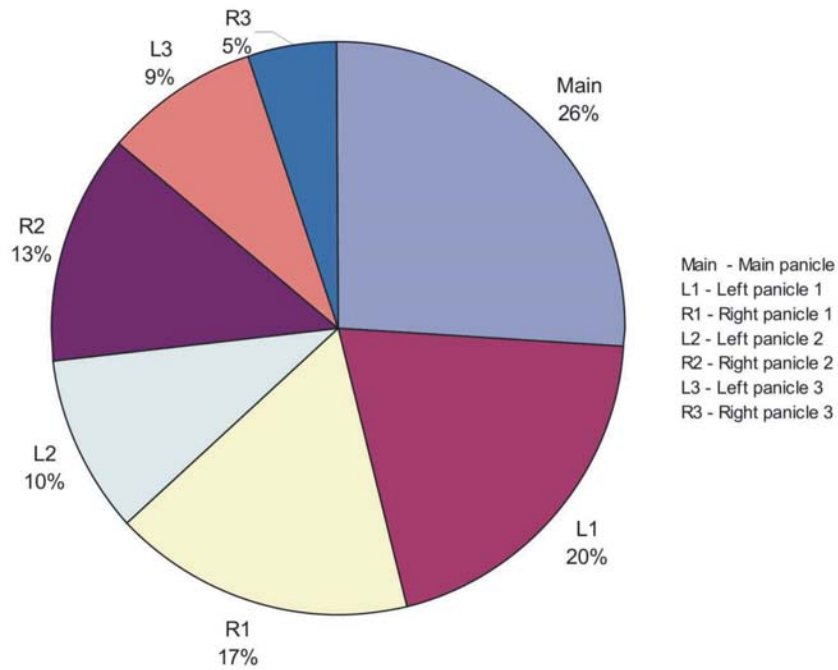

Fig. 4. Average per cent seed yield contribution from panicles born on tight and left side of the sorghum mutant under normal conditions

exploit its genetic potential, the mutant was involved in a full diallele study along with ruling varieties (A-1, M 35-1, 104 B, M 31-2B and CSV 216 R) to assess the combining ability and to quantify the magnitude of heterosis. SbABM performed exceptionally well in hybrid combinations for all the traits. Mean squares due to genotypes were highly significant for all the traits. The results on general combining ability revealed that SbABM was significantly a better general combiner for all the traits. Majority of the hybrids involving SbABM as parental line exhibited high degree of heterosis for most of the traits, finally contributing to overall vigour of the plant. However, SbABM did not restore fertility on both *milo* and *maldandi* cytoplasm.

Conclusion

Apart from being an excellent material for basic studies, the mutant has an immediate value for commercial cultivation. It can serve as an important source for diversification of Maldandi and its relatives in the farmers' field. There is a need for the complete understanding of the regulation of branching, by environmental, hormonal and genetic factors and their interactions. In this direction, emphasis should be given to investigate molecular mechanisms associated with the regulation of branching by environmental and hormonal factors.

References

Gomez KA and AA Gomez (1984) Statistical procedures for agricultural research (2 ed.). John Wiley and sons, New York, 680 p.

Immadi SU, SS Patil, MS Maralappanavar and GM Sajjanar (2014) Penetrance, expressivity and inheritance of axillary branching in somaclonal mutant of sorghum (*Sorghum bicolor* L.). *Euphytica* **196**: 449-457.

Immadi S, MS Maralappanavar, SS Patil and GM Sajjanar (2016) Translation of phenotypic diversity of *Sorghum bicolor* axillary branched mutant into exploitable heterosis *Plant Breed.* **135**: 177-190.

Kebrom TH, BL Burson and SA Finlayson (2006) Phytochrome B represses Teosinte Branched1 expression and induces sorghum axillary bud outgrowth in response to light signals. *Plant Physiol.* **140**: 1109-1117.

Kerstetter RA and S Hake (1997) Shoot meristem formation in vegetative development. *Plant Cell* **9**: 1001-1010.

Maralappanavar MS, S Kuruvinashetti and CH Chandrashekhar (2000) Regeneration, establishment and evaluation of somaclones in *Sorghum bicolor* (L.) Moench. *Euphytica* **115**: 173-180.

McSteen P and O Leyser (2005) Shoot branching. *Ann. Rev. Plant Biol*. **56**: 353-374.

Schmitz G and K Theres (1999) Genetic control of branching in Arabidopsis and tomato. *Curr. Opin. Plant Biol.* **2**: 51–55.

Ward SP and O Leyser (2004) Shoot branching. *Curr. Opin. Plant Biol.* **7**: 73-78.