Indian J. Genet., 69(4) (Spl. issue): 335-343 (2009)

Specialty corn hybrids - new strategy and perspective of maize in climate change

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Abstract

Specialty corns attract particular attention on account of steady increase in demand and production over the recent years in India as well as their utility in adjusting to drought conditions. To address major limitation of low productivity, initiatives were made towards developing single cross hybrids in baby corn, sweet corn and pop corn. Respective quality parameters relating to tender ear characteristics (baby corn) biochemical components relating to sweetness (sweet corn) as well as popping parameters (pop corn) were considered. Diverse maize genotypes were identified for baby corn purpose and new experimental hybrids in baby corn were developed. In respect of sweet corn, elite hybrids superior to the checks (Madhuri and Priya) in terms of productivity and quality were identified. Elite hybrids in pop corn were identified meeting the requirement of quality and productivity in comparison to respective checks. This initiative is expected to give much needed impetus at realizing the potentiality of specialty corns in general and for adapting to adverse effects of climate change in particular. Further, by using elite hybrids of all specialty corns (including QPM) as well normal field corns together, a multiple range of options and products can be contemplated with potential benefits to farmers. Such strategy and plan for using diverse maize types for ensuring continuous and wide range of harvesting duration is indicated.

Key words: Maize, specialty corns, hybrids, climate change

Introduction

Maize (*Zea mays* L.) occupies an important place in world agriculture, being grown in more than 150 countries, including USA, China, Brazil, Mexico, France and India. It is the third most important cereal crop in India after rice and wheat with an area of 8.12 m. ha. and production of 19.77 million tones with average productivity of 2.4 tonnes/ha during 2007-08 [1]. Maize is being grown for diverse uses, including as vegetable, like baby corn and sweet corn in addition to usages as a popular snack in the form of pop corn. Compared to normal/field corns, specialty corns possess additional and characteristic features. Their global spread, increasing demand and premium price make them attractive options for the farmers in many countries including India. Another uniqueness of specialty corns is their amenability for multiple options ensuring a wide range as well as multiple options pertaining to harvest time and various economical products. This feature is especially important in the context and consequences of ill effects of climate change, as unusual and extreme variations could be better handled taking advantage of the flexibility provided by specialty corns.

Due to limited research initiatives till now, cultivars with high productivity in each of these three types of corn are not available. Currently some of the early maturing maize cultivars originally developed for grain usage are grown for baby corn purpose and limited efforts are being made towards assessment of specific parameters [2, 3]. In India, green ears of starchy field corns are also consumed in various forms while sweet corns are more suited for such usage. However only three composites of sweet corn are currently available under public domain. Different approaches for sweet corn improvement have been highlighted [4-6], including emphasis and importance of vegetable maize and utility of field corns in the improvement of specialty corns [7, 8].

Out of the various specialty corns, popcorn (*Zea mays everta*) has a very big market potential as a popular snack cereal especially if the processing and packing needs from large scale production are taken care of. Presently, popcorn is an important commercial crop throughout the world and its production has been steadily increasing for decades [11]. Hence, there is an enormous opportunity and potentiality not only in

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Published by Indian Society of Genetics & Plant Breeding, F2, First Floor, NASC Complex, PB#11312, IARI, New Delhi 110 012
Online management by indianjournals.com

domestic market but in international market as well. In India, improvement of popcorn genotypes has received little attention and till now only few composites have been released (Amber popcorn and VL pop).

In this context the present research efforts encompass identification of elite single cross hybrids in each of the three categories of specialty corns *viz*., baby corn, sweet corn and pop corn. The overall strategy included assessment and characterization of respective source populations, evaluation of the performance of experimental hybrids for productivity and quality parameters in different locations; identification of elite hybrids exhibiting standard heterosis over the respective commercial checks. Also, possibility of simultaneous cultivation of these specialty corn hybrids as a strategy for addressing ill effects of climate changes with the prospect of efficient use of available resources is suggested. While baby corn can be cultivated along with all other types of corns including the field corns, strategies like isolation (time and/or space), pollination control during specific critical duration would be required for simultaneous cultivation of other types of specialty corn to maintain their respective desired qualities.

Material and methods

Baby corn

Baby corn is the tender ear of the corn harvested from a crop of 45-70 days duration (depending upon genotypes and seasons) when silk (1-3cm) has just emerged and no fertilization has taken place. It is a small young corn ear harvested at the stage of silk emergence which following de-husking and separation of silks is used as vegetable. For the present study, eighteen early maturing maize genotypes comprising of composites, experimental hybrids and inbred lines (Table 1) were selected for comprehensive evaluation under dense planting. Yield and quality parameters were assessed in all the genotypes, including two checks, one each of composite (VL baby corn-1) and hybrid (HM-4). Data collected on different characters were analyzed using Mahalanobis's D^2 statistics. In addition, ten potential genotypes were used for generating experimental hybrids, for identification of elite hybrids for exclusive use as baby corn.

Sweet corn

Sweet corns (*Zea mays saccharata*), consumed at green ear stage, possess specific endosperm mutations contributing to enhanced sweetness. Six sweet corn lines, three each belonging to *su* and sh_2 groups were involved in generating hybrids. In addition, seven field corn lines were used for developing twenty eight elite crosses using four sweet corn genotypes in L x T design. Particulars regarding the sweet corn and normal maize genotypes in the two experiments are also given in Table 1.

Pop corn

The material consisted of 10 inbred lines (IPPA-14, 17, 19, 20, 33, 34, 35, 37, 38, and IPPA-39), derived from different source populations. The 45 F_1 along with ten parental lines and check were planted in a Randomized Block Design with 3 replications. Each entry was represented by a 2 row plot of 5 metre length with a row-to-row spacing of 75 cm. Five plants were tagged randomly from each row and subsequently all observations were recorded on them. Evaluation trials of diallel were conducted at IARI, New Delhi during *Kharif* 2007 and at Pusa Bihar in *Rabi* 2007-08. The popping quality analysis of 44 inbred lines and diallel crosses was carried out in Maize Genetics Unit, IARI and Directorate of Maize Research New Delhi.

The characters studied in two experiments comprised of yield parameters and quality traits (Popping percentage, Popping expansion and Flake volume). The average F_1 values over replications were used for the estimation of heterosis expressed in percentage over mid parent value (MP), better parent value (BP) and best standard check. The computation of values was done as per [12]. The parent with higher mean was considered better for all the traits except for flowering parameters, where parents with lower mean were considered better for estimation of heterosis

Result and discussion

Baby corn

Analysis of variance revealed significant differences among the genotypes for 10 characters studied, indicating that data generated could be effectively utilized. The results of multivariate analysis indicated the presence of considerable divergence among the eighteen genotypes studied. On the basis of Mahalanobis' D^2 statistics as per [9], genotypes were grouped in 6 clusters by Wards dendrogram. Cluster–IV, comprising 8 genotypes was biggest, followed by cluster-I, with 4 genotypes. The maximum inter-cluster distance was (65.61) between cluster II and III, followed by cluster II & V (49.84) (Fig. 1).

Table 1. Particulars regarding baby corn and sweet corn genotypes

A. Baby Corn		B. Sweet Corn		
Genotypes	Particulars	I. Diallel analysis		Particulars/remarks
1.VL Baby corn 1	Check, baby corn	Parents	Code#	
2.Vivek hybrid 9	Elite QPM hybrid	P_1 (*su*)	SCI 301	Sweet corn genotypes, conforming to two classes of su and sh2
3.Vivek QPM-9	Elite QPM hybrid	P_2 (*su*) P_3 (*su*)	SCI 302 SCI 303	
4.Vivek hybrid 27	New hybrid	P_4 (*sh2*)	SCI 309	
5. MBD-08-6834	Elite inbred	P_5 (*sh2*) P_6 (*sh2*)	SCI 306 SCI 307	
6. MBD-08-6835	-do-			
7. MBD-08-6837	-do-			
8. MBD-08-6838	-do-	II. L X T Analysis		
9. MBD-08-6839	-do-	A. Seven Lines: Field corn		
10. MBD-08 6409 x 10	Elite hybrid	DMB 321 to DMB 327		Elite maize inbred lines derived from four source populations
11. MBD-08 6411 x 12	-do-			
12. MBD-08 6413 x 14	-do-			
13. MBD-08 6415 x 16	-do-	B. Four testers: Sweet corn		
14. MBD-08 CM135	Parent inbred	SCI 302, (su)		
15. MBD-08 CM142	Parent inbred	SCI 303, (su)		
16. MBD-08 CM151	Parent inbred	SCI 304, (sh2)		Elite sweet corn inbred lines
17.MBD-08-7000 (IPA510)	Parent inbred	SCI 305, (sh2)		
18. HM-4	Elite Hybrid			

Based on divergence studies crosses may be effective between genotypes of cluster –II (VL Baby Corn –I) and cluster-III (6835 & CM151) followed by cluster-II and cluster-V. Parents may be selected for hybridization based on their combining ability values and *per se* performance to isolate good recombinants. Based on Mahalanobis' D^2 analysis character which is contributing highest to total divergence is brix reading in % (35.29%), followed by days to tasseling (31.37%) and hardness (10.46%), while the remaining characters contributed less to the total divergence (Table 2). Selection of parents for hybrid breeding programme is the first and of paramount importance in practical utilization of heterosis. Earlier studies have indicated that more number of heterotic combinations with higher level of heterosis was from parents grouped into moderate divergent groups [10]. Hence, selection of varieties for hybridization should be more based on genetic diversity than other considerations like geographic diversity. Using diverse maize genotypes identified for baby corn purpose, new experimental hybrids in baby corn were developed (Fig. 2) and comparative evaluation with the checks was undertaken.

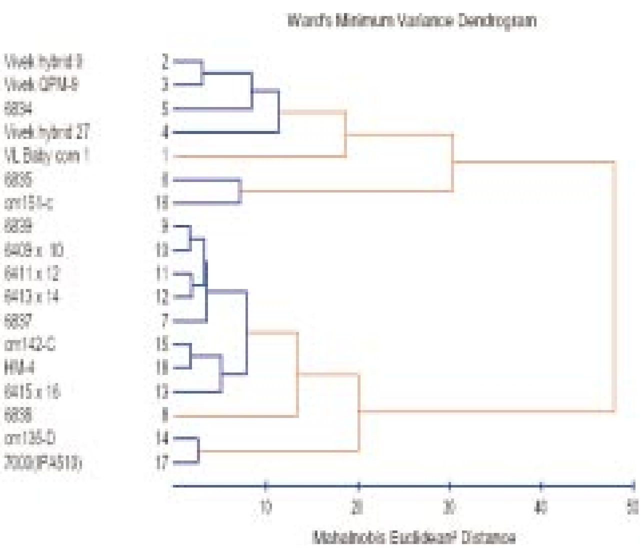

Fig. 1. Cluster diagram with inter and intra cluster distances

Table 2. Characters and their % contribution to total diversity

Characters		Contribution %
1	Number of cobs	0.00
2	Cob weight with husk	2.61
3	Cob wt. no husk	6.54
4	Number of plants/ replica	2.61
5	Fodder wt (kg)	2.61
6	Dry wt. of 1kg fodder (gm)	3.92
7	Brix reading in %	35.29
8	Days to tasseling	31.37
9	Days to silking	4.58
10	Hardness (force in kg)	10.46

Sweet corn

Among the sweet corn inbreds, P_6 and P_4, belonging to shrunken type with higher sugar content were found to be better combiners for this trait. Of the seven crosses identified in each season, four (P_1 x P_5, P_2 x P_5, P_3 x P_5 and P_3 x P_6) were found to be promising in both *Kharif* and *Rabi* seasons and green ear of sweet corn is indicated in plate 2. Further, as a long term strategy, introgression of enhanced sweetness trait in to field corns was attempted, to enlarge diversity in sweet corn germplasm and to transfer desirable attributes into each other between the two groups of corns, following L x T design. From the comparative analysis, L_5 and L_6 were identified as good combiners for early maturity and L_2 for yield and sugar content on the basis of GCA effects. Further, of the 28 crosses developed and evaluated, L_1 x T_2, L_6 x T_4, and L_3 x T_2 hybrids were identified as best specific combiners for early maturity, field emergence and fresh ear weight while L_7 x T_2 had better specific combining ability for grain yield, TSS, total as well as non-reducing sugars. Further, hybrid L_2 x T_3 had high *per se* performance for mean fresh ear weight (247g) as well as higher total sugar content (15.5%) at dry kernel stage. These elite combinations can be further advanced to select sweet corn lines with improved plant stand and yield and field corn lines with enhanced sugar content.

Pop corn

The range of heterosis % over mid parent (M.P.), better parent (B.P.) and check for Delhi and Bihar are presented in Table 4 and 5 respectively. Three top parents with their mean values, three top F_1 hybrids with heterosis % over M.P., B.P. and check have been presented in the same table. The heterosis over better parent for ear length and ear diameter indicated that some of the hybrids (IPPA-17 x IPPA-19 and IPPA-15 x IPPA-38) were stable over the environments. Photograph of a well popped corn is indicated in plate 3. This indicates that there is less G x E interaction for these hybrids. The better parent heterosis was observed to be as high as 58.37% for ear length and 50.83% for ear diameter at Bihar while it was 82% and 39% respectively at Delhi. Such high heterosis for yield component is not unusual in maize and has been reported earlier [13-16].

The present study attempted to identify superior hybrids for popping quality comprising of popping percentage, popping expansion and flake volume along with high yield. Here the cross IPPA-20 x IPPA-35 revealed 10% heterosis over the check at Delhi, while IPPA-19 x IPPA-20 (21.94) recorded highest heterosis for popping percentage at Bihar. The cross IPPA-14 x IPPA-34 recorded a highest of 35% heterosis over mid parent at both the locations. Manifestation of standard heterosis for popping expansion and flake volume was more pronounced at Bihar (Tables 3 and 4) . The cross IPPA-20 x IPPA-37, IPPA-20 x IPPA-37, IPPA 33 x IPPA 37 and IPPA-35 x IPPA-37 had high popping quality and hence these two hybrids can be further evaluated for popping percent, popping expansion and flake volume. These hybrids also recorded high level of heterosis for flake volume at both the locations indicating wider adaptability of these crosses across the locations. Similar kind of study was also conducted by [15, 17], who reported high heterosis for popping expansion and flake volume. Interestingly, the three elite crosses identified on the basis of popping quality parameters as well as reasonable productivity, as discussed above, involve IPPA 37 as a common male parent, in combination with IPPA 20, IPPA 33 and IPPA 35 as female parents. Hence, large quantity of hybrid seed of these combinations could be produced simultaneously with relative ease, ensuring the production of three pop corn hybrids from a single location.

Strategy and plan for simultaneous cultivation of different maize types

Thus, the initiatives elaborated above dealing with the development of single cross hybrids in the three types of specialty corns with high productivity and quality could

Fig. 2. Husked and dehusked babycorn from an elite hybrid

Fig. 3. Sweet corn green ears from an elite hybrid

facilitate their faster spread and popularization with multiple benefits to different stake holders. Further, development of elite hybrids meeting the twin requirements of higher productivity and quality would be very essential to enlarge the cycle of production, consumption and acceptance at both national and global markets. Further, taking into account availability of elite hybrids in QPM as well as numerous single cross hybrids of field corn belonging to different maturity groups, a strategy for their simultaneous use can be proposed (Table 5). Multiple options, a wide range of harvesting duration as well as products could be contemplated to take advantage of available resources in a more judicious way. The prospects for multiple uses of each type of maize also gives the much needed flexibility of options in the context of global climate change, with its characteristic feature of uncertainty and extremities in the climatic factors like rainfall and temperature. Hence, depending upon the actual conditions in a growing season as well as local market situation, the farmers can plan for different emphasis and volume for each of the three options elaborated.

A note of caution in the simultaneous use of the three options is to be kept in mind, especially while clubbing the options II and III, to ensure time or space isolation so as not to affect the quality of each of their

Fig. 4. Popped kernels from an elite genotype

products. On the other hand, option I. pertaining to baby corn can be readily taken up with the others options (by ensuring timely removal of tassels from the baby corn maize genotypes before pollen shedding). From above illustrations, it is evident that unique features of maize crop can be effectively utilized in the context of global climate change in general and to Indian scenario in particular. The huge potentiality of each of the specialty corns and field corns through hybrid technology individually as well as in a strategy of simultaneous use would facilitate better adjustment to climate change effects as well as harnessing multiple benefits.

Table 3. Range of Mean Values of different characters in parents, F_1 hybrids & heterosis at Delhi

Characters	Plant height(cm)	Days to 50% silk	Days to 50% pollen	Ear height	Ear length	Ear diameter	Kernel rows/ear
Range of mean values							
Parents	158.33-206.67	60.67-65.00	52.67-62.33	60.00-101.67	10.14-14.89	1.99-2.57	10.13-12.53
F_1	203-03-248.33	55.67-65.00	52.67-62.33	101.67-136.67	13.74-70.30	2.50-3.23	14.53-15.40
Range of Heterosis % over							
M.P.	6.33-44.79	-12.21-4.25	-13.11-4.14	5.79-80.25	6.73-58.89	-0.66-43.55	7.87-49.51
B.P.	0.81-43.30	-13.85-1.54	-14.89-1.07	-1.64-62.22	-6.78-52.63	-1.59-39.50	2.13-47.13
Check	24.51-52.07	-11.21-2.07	-12.654-2.27	-13.04-18.84	29.62-74.58	10.87-50.62	1.87-25.20
Three top F_1 hybrids with	IPPA-34xIPPA-35 (52.07)	IPPA-14xIPPA-20 (-11.21)	IPPA-14xIPPA-17 (-12.65)	IPPA-17xIPPA-33 (18.84)	IPPA-19xIPPA-38 (74.58)	IPPA-17xIPPA-19 (50.62)	IPPA- 17xIPPA-34 (25.54)
heterosis % over check	IPPA-35xIPPA-37 (51.05)	IPPA-14xIPPA-17 (-10.69)	IPPA-14xIPPA-20 (-12.11)	IPPA-35xIPPA-39 (14.50)	IPPA-37xIPPA-38 (70.69)	IPPA-14xIPPA-35 (44.41)	IPPA-20xIPPA-34 (23.91)
	IPPA-14xIPPA-39 (47.99)	IPPA-20xIPPA-35 (-10.06)	IPPA-20xIPPA-35 (-12.10)	IPPA-19xIPPA-37 (11.59)	IPPA-17xIPPA-39 (63.60)	IPPA-14xIPPA-17 (44.10)	IPPA-20xIPPA-35 (22.83)
Characters	Kernels/row	100 seed weight (gm)	Moisture content (%)	Yield per plant (gm)	Popping (%)	Popping expansion	Flake volume (cc)
Range of mean Values							
Parents	15.87-24.60	11.25-16.49	21.43-34.07	55.42-91.25	52.67-88.33	7.97-15.32	229.17-376.33
F_1	28.20-39.20	14.28-22.12	17.20-35.47	86.25-144.58	57.33-94.00	5.92-19.85	215.00-510.00
Range of heterosis % over							
M.P.	28.43-114.29	- 1.06-58.82	-42.62-33.58	33.14-168.13	-31.47-35.39	-49.63-53.03	-37.29-88.82
B.P.	22.80-93.88	-9.08-51.96	-45.68-21.88	30.81-136.13	-35.09-21.72	-55.12-37.47	-38.18-77.73
Check	56.67-117.78	3.48-60.29	-34.85-34.36	38.84-128.83	-32.79-10.16	-56.10-45.95	-22.38-84.36
Three top F_1 hybrids with heterosis % over check	IPPA-37xIPPA-38 (117.38)	IPPA-17xIPPA-19 (60.29)	IPPA-37xIPPA-39 (98.88)	IPPA-17xIPPA-20 (128.83)	IPPA-20xIPPA-35 (10.16)	IPPA-20xIPPA-37 (45.54)	IPPA-20xIPPA-38 (84.36)
	IPPA-17xIPPA-20 (1210.72)	IPPA-17xIPPA-38 (57.90)	IPPA-33xIPPA-38 (83.93)	IPPA-20xIPPA-34 (124.54)	IPPA-19xIPPA-20 (8.98)	IPPA-37xIPPA-38 (29.16)	IPPA-35xIPPA-37 (77.50)
	IPPA-35xIPPA-39 (108.50)	IPPA-17xIPPA-39 (44.93)	IPPA-20xIPPA-37 (79.63)	IPPA-34xIPPA-38 (122.70)	IPPA-19xIPPA-34 (8.59)	IPPA-35xIPPA-37 (26.96)	IPPA-33xIPPA-37 (61.85)

Table 4. Range of Mean Values of different characters in parents, F_1 hybrids & heterosis at Pusa Bihar

Characters	Plant height(cm)	Days to 50% silk	Days to 50% pollen	Ear height	Ear length	Ear diameter	Kernel rows/ear
Range of mean values							
Parents	165.00-213.33	65.00-69.00	62.00-66.00	83.33-105.00	11.31-16.04	2.21-2.77	10.60-13.07
F_1	210.00-260.00	60.00-69.00	59.33-66.00	96.67-151.67	15.18-19.94	2.56-3.33	13.33-16.47
Range of heterosis % over							
M.P.	3.23-45.71	- 7.96-2.50	- 8.51-2.92	2.65-70. 09	12.98-60.35	4.6-50.94	6.28-52.00
B.P.	0.00-40.57	- 10.63-2.56	- 10.10-2.65	- 7.94-59.65	0.39-58.37	- 3.03-50.83	2.81-48.80
Check	17.76-45.80	- 2.94-11.76	-12.70-1.45	- 14. 70-33.83	26.17-67.28	19.07-54.88	1.55-27.97
Three top F_1 hybrids with heterosis % over check	IPPA-17xIPPA-34 (45.80) IPPA-34xIPPA-35 (42.99)	IPPA-14xIPPA-19 (-11.76) IPPA-14xIPPA-20 (-10.29)	IPPA-14xIPPA-19 (-12.70) IPPA-14xIPPA-17 (-12.18)	IPPA-14xIPPA-39 (33.83) IPPA-14xIPPA-38 (32.36)	IPPA-19xIPPA-38 (67.28) IPPA-37xIPPA-38 (62.08)	IPPA-20xIPPA-34 (54.88) IPPA-17xIPPA-19 (53.95)	IPPA-17xIPPA-34 (27.97) IPPA-20xIPPA-35 (23.31)
	IPPA-19xIPPA-33 (42.99)	IPPA-14xIPPA-17 (-10.29)	IPPA-34xIPPA-38 (-10.66)	IPPA-17xIPPA-33 (25.01)	IPPA-33xIPPA-39 (57.72)	IPPA-14xIPPA-35 (49.30)	IPPA-20xIPPA-34 (22.22)
Characters	Kernels/row	100 seed weight (gm)	Moisture content (%)	Yield per plant (gm)	Popping (%)	Popping expansion	Flake volume (cc)
Range of mean values							
Parents	17.60-28.00	11.93-17.71	26.27-35.40	49.16-92.06	59.67-89.33	8.47-15.27	240.00-383.33
F_1	29.00-41.80	13.95-22.51	18.17-35.40	93.75-155.42	72.33-96.33	9.66-21.04	221.67-521.67
Range of heterosis % over							
M.P.	20.08-90.19	- 0.024-58.40	- 44.21-14.35	33.14-168.13	- 14.79-38.42	- 45.43-63.54	- 29. 27-81.45
B.P.	16.91-73.93	- 11.13-50.40	- 46.23-9.37	7.76-155. 64	- 23.17-35.11	- 51.06-46.30	- 37.39-78.86
Check	76.05-128.04	6.13-60.44	- 1.41-86.65	60.47-168.99	- 16.04-21.94	- 45.11-71.34	- 9.74-103.25
Three top F_1 hybrids with heterosis % over check	IPPA-34xIPPA-38 (128.04) IPPA-37xIPPA-38 (121.49) IPPA-38xIPPA-39 (117.13)	IPPA-17xIPPA-19 (60.44) IPPA-17xIPPA-38 (55.24) IPPA-14xIPPA-35 (44.98)	IPPA-37xIPPA-39 (86.65) IPPA-33xIPPA-38 (80.85) IPPA-20xIPPA-37 (79.44)	IPPA-17xIPPA-20 (168.99) IPPA-20xIPPA-34 (163.57) IPPA-17xIPPA-19 (161.24)	IPPA-19xIPPA-20 (21.94) IPPA-20xIPPA-35 (21.10) IPPA-19xIPPA-35 (17.30)	IPPA-20xIPPA-37 (17.34) IPPA-35xIPPA-37 (46.25) IPPA-33xIPPA-37 (44.71)	IPPA-20xIPPA-37 (103.25) IPPA-33xIPPA-37 (79.22) IPPA-19xIPPA-39 (75.32)

Table 5. Features of diverse maize types and various options to harness the benefits of multiple products

Types of maize and specific characteristics	Option-I* Products: baby corns+Fodder Duration:45-60 days	Option-II Products: Green ears+Fodder Duration: 65-70 Days	Option-III Products: Dry Kernel +Fodder Duration: 85days &above	Recommended and Appropriate maize Genotypes
Baby corn (Early maturity, prolificacy, tender ear and quality traits)	Main product	Possible	Possible	New single cross hybrids Extant cultivars parti-cularly belonging to early maturity.
Sweet corn (Genotypes with specific endosperm mutation, like *su* and *sh2*)	Possible	Main product	Possible and important for seed production; but currently limited commercial use	New sweet corn SCH; Madhuri, Priya, Win Orange (Extant sweet corn composites)
Pop corn (Genotypes with specific popping feature and related characteristics)	Possible	Possible; Limited use	Main product; commond premium price	New SCH; Extant pop corn cultivars (Win Pop, Almora Pop, Pearl pop etc.)
QPM (Genotypes with 2-3 times higher essential amino acids-Lysine and tryptophan)	Possible	Possible with potential benefits	Main product with additional advantage for value added products. (Chips, Biscuits)	QPM cultivars; Shakti, Shaktiman-I, HQPM1,2,5, etc.
Normal/Field corn (Currently major group; Conforming to different maturity groups)	Possible	Possible	Main product; currently, major share in maize production	Extant single cross hybrids(and composites); belonging to : Extra-early; early, medium and late maturity groups

*Only Option I can be clubbed readily with other two , without affecting the quality of all the products ; For the other two, time or space isolation is required to ensure the desired quality of the products.

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