ISSN 2278-8867

MAIZE JOURNAL

(An International Journal of Maize Research and Related Industries)

Volume 9 • Number 2 • October 2020

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2011

Maize Technologists Association of India
Pusa Campus, New Delhi 110 012

The association was founded with the following Objectives:

1. To bring together all professionals from public and private organizations involved in maize research , extension, production, processing, value addition, seed production/ marketing, energy, socio-economic and environmental iss ues.
2. To facilitate linkages among maize stake holders to disseminate up-to-date and relevant technology/i nformation needed for end through organizing conferences/symposia/ seminars/ meetings, *etc.*
3. To publish a multidisciplinary scientific journal of international standards exclusively devoted to the maize research named "Maize Journal"

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The Maize Journal is published half yearly by the Maize Technologists Association of India. The Journal publishes papers based on the results of original research on maize and related issues in the following areas:

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Mandate

1. **To publish peer reviewed original research papers, short communications and critical review on all aspects of maize research and related industries.**
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Maize Journal (October 2020) 9(2): 65-70

MINI REVIEW

Maize as a chief source of quality feed and fodder for intensified and sustainable livestock husbandry in Karnataka

P. Mahadevu[1] · B. G. Shekara[1] · N. M. Chikkarugi[1] · N. Manasa[1] · Puttaramnaik[2] · D. Shobha[2] · N. Mallikarjuna[2]

Abstract: Karnataka is the leading state with highest growth rate in maize area (7.74 per cent) and production (7.64 per cent) in the country. Between 2014-15 to 2019-20, maize area rapidly increased from 11.86 lakh ha to 13.97 lakh ha and production from 22.23 lakh tons to 47.68 lakh tons and productivity from 2830 to 3414 kg/ha mainly replacing rice, ragi, sorghum, bajra, cotton, tobacco and vegetable crops in the state. This increase is associated with corresponding increase in the demand from fast growing poultry and dairying sectors in the state. Maize is also grown as major animal forage cereal for green fodder along with dual purpose baby corn and sweet corn. In predominant dairy sector maize is the chief source of cattle feed and green fodder in the state. Maize can play a key role in bridging the gap between demand and supply of feed and fodder in both quantitatively and qualitatively through supply of energy and essential nutrients through bio-fortified maize hybrids. Maize is also emerged as one of the most important crop with industrial uses in the state.

Keywords: Diversified uses · Feed · Fodder · Industrial · Maize · Nutritional quality

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Received: 03 June 2020/ Accepted: 31 July 2020

Introduction

Karnataka is the leading state in maize as multi-purpose crop for food, feed, fodder and industrial uses and stands first in area and production in the country (Figure 1). Maize is grown in more than 26 out of 30 districts except coastal and malnad districts in the state. Eight districts having significant area of more than fifty thousand hectares (Belgaum, Bellary, Chitradurga, Davanagere, Haveri, Hassan, Shimoga, Mysuru, and Chamarajanagara). Maize is cultivated both under rainfed (80 per cent) and irrigated conditions (20 per cent) and is fast catching up in, peri-urban areas for green cob, baby corn, sweet corn and popcorn to the needs of cosmopolitan population. The area under Rabi is increasing with higher productivity (> 4800 kg/ha), relatively lower cost of production and easy cultivation. Rapid growth of poultry, dairy and animal husbandry led to higher demand for maize which contributed to increased maize area in Karnataka (Figure 4). Southern states gain highest share in poultry production and consumption. These states also recorded significant increase in livestock population (20th livestock census, GOI-2019) as compared to previous census with greater contribution of livestock to GDP as compared to agriculture sector. There are private seed companies involved in maize seed production and distribution to the tune of more than 2.5 lakh quintals annually. This also facilitates seed production of parental lines and hybrids to meet the growing demand immediately in the subsequent season. The surplus maize produced also move to neighboring states like Tamil Nadu, Andhra Pradesh, Maharashtra, Kerala and Goa.

The important factors influenced quick spread and area expansion of maize in the state are:

1. Maize can be grown in all the three seasons throughout the year in majority areas of the state.
2. Higher concentration of poultry and dairying increased demand for quality feed for which maize is a chief ingredient.
3. Rapid urbanization enhanced cultivation of maize for sweet corn, baby corn, popcorn and green cob apart from maize mainly for grain production followed by green fodder production. Dual purpose maize for baby corn, sweet corn and green corn with additional green fodder and normal maize hybrids with stay green type frequently harvested at milky stage for green fodder and silage production.
4. Multiple uses of maize starch, grain and other products in various industries also kept high demand for grain and improved quality maize production.

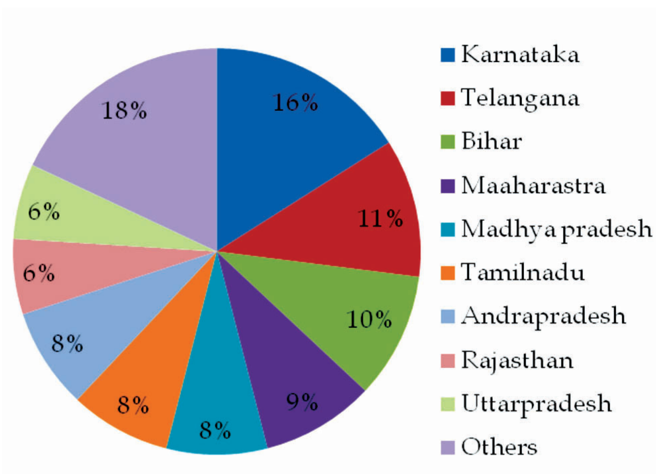


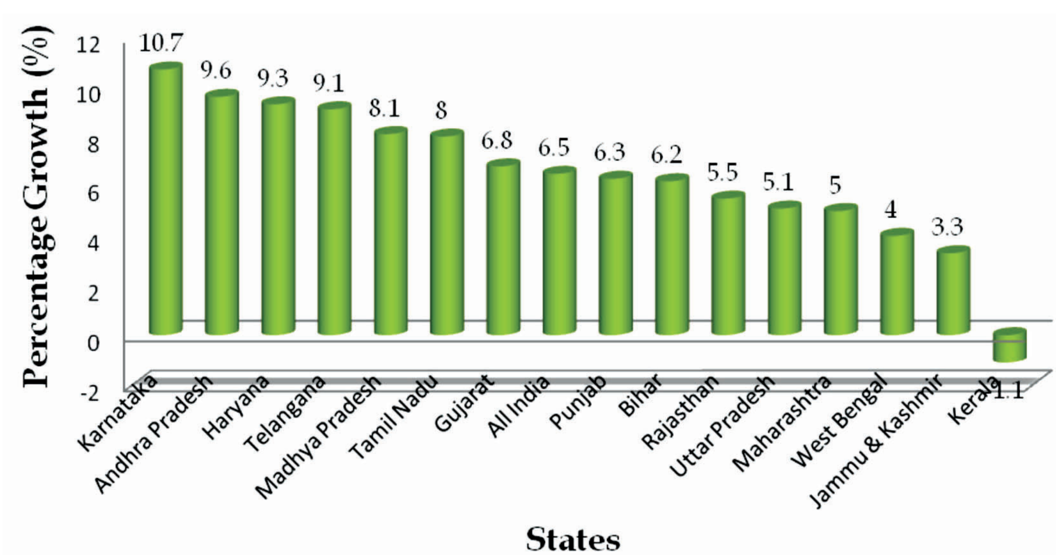
Figure 1. Highest share of Karnataka in Maize area

5. Active participation and promotion of high yielding single cross hybrids by prominent private companies accelerated exponential growth in maize area and production in the state.
6. There is continuous demand for maize grown in Karnataka from states like Tamil Nadu, Andhra Pradesh, Maharashtra, Goa and Kerala due to higher concentration of feed manufacturing industrial clusters in these states.
7. Major maize based companies have production in Karnataka with processing facilities.

Status of animal husbandry in Karnataka

According to the 2019 Livestock census (Table 1) in the state, total bovine population is 144.94 lakhs, among which the population of cattle is 117.50 lakhs and that of buffaloes is 27.30 lakhs, respectively. Out of 117.50 lakhs cattle population, 80.65 lakhs are indigenous, 36.99 lakhs are cross bred. There was significant increase of 78 per cent in cross bred cows in the state indicated higher role of maize in feeding these milching cows. The population of sheep is 111 lakhs with increase of 54 per cent and that of goats is 61 lakhs with increase of 38 per cent (*Source*: Directorate of Animal Husbandry and Veterinary Services, Bangalore). The growth pattern of milk (Figure 2) & meat production (Figure 3) indicated highest growth rate in Karnataka (10.7 per cent) followed by Andhra Pradesh, Telangana and Tamil Nadu with more than national average of 6.5 per cent. The per capita availability of milk in most of the southern states is lower; hence there is a

Figure 2. State-wise Annual growth of Milk Production during 2018-19 in India.



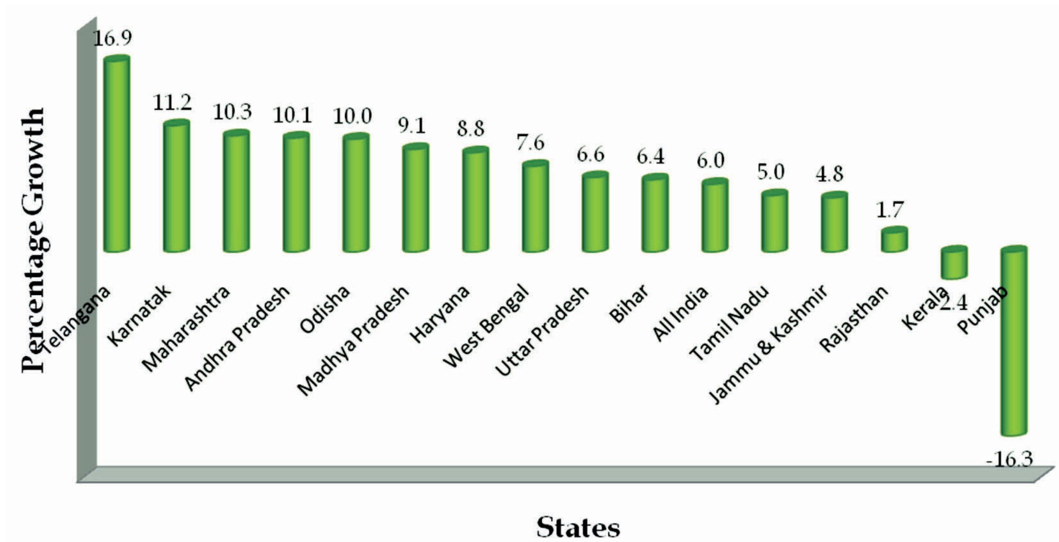
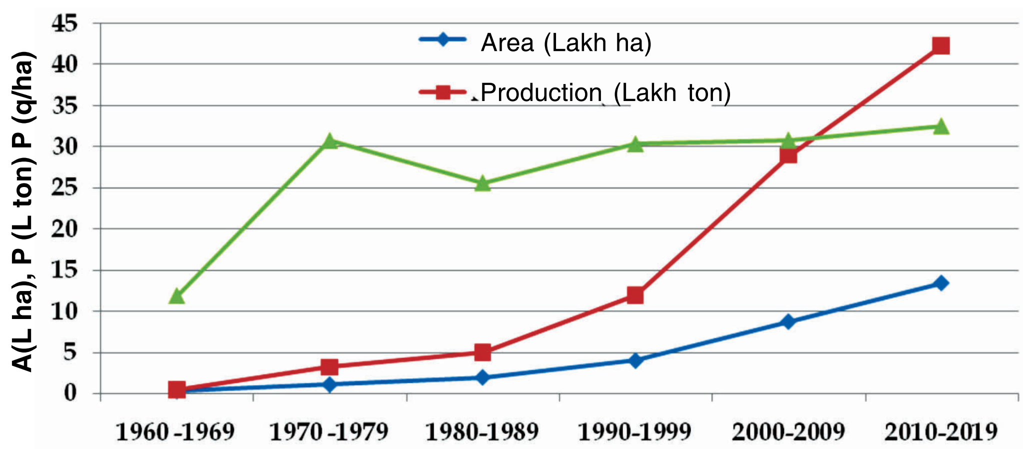


Figure 3. Annual Growth rate of 15 Major Meat Producing states for the year 2018-19



Figrue 4. Decadal growth of Maize crop in Karnataka

scope to improve milk productivity and quality. Alternatively these southern states are producing highest number of eggs with improved per capita availability as chief source of protein to large population due to increased demand for animal protein. State-wise meat (Figure 3) production during the year 2018-19 also indicated higher growth rate in these southern states due to proportionate growth in area production and productivity of maize in the region.

Maize in dairying sector

Maize plays an important role in increased dairying with majority of animal husbandry carried out in rural area by small and marginal farmers as highest number of dairy cooperatives are distributed in southern Karnataka. The farmers give equal importance while growing baby corn, sweet corn and green corn both for maize cobs and green fodder fulfilling green fodder requirements significantly. Dairy cooperatives supply fodder maize seeds to all its dairy farmers for green fodder seasonally. Maize is highly preferred for silage making and hydroponic fodder production due to its quality and high biomass yield. Hydroponic fodder production is picking up in peri urban due to less water and space requirement and hygienic fodder production.

Role of maize in poultry sector

Maize is an important ingredient in poultry feed with steady demand for more than 50 per cent of the maize produced in the state goes to poultry feed manufacturing. Majority of organized poultry farms and processing units are located in Karnataka and neighboring states (APTEC Report, 2018). The main maize poultry value chain involves maize farmers, breeders, seed distributors, poultry producers, retailer and consumers. The continued growth of poultry sector offers remunerative and stable price and

Table 1. Livestock scenario in Karnataka

Particulars	Population (Million) 2012	Population (Million) 2019	% Change
Sheep Population	9.6	11.1	15.31
Goat Population	4.80	6.17	28.63
Poultry Population	53.4	59.5	11.33
Livestock Population	27.7	29.0	4.70

Source: 20th, Livestock Census, 2019, GoI

market for accelerating maize production. Poultry ration consists of 60-65 per cent maize and 28-30 per cent soybean meal and other substitutes like broken rice, bajra, sorghum, fish meal, sunflower and groundnut meal and rice bran. Since, feed accounts 70-75 per cent of total operational cost, improving feed efficiency is important in maximizing profitability. Bio-fortified maize with enriched nutrients is needed to be popularized to meet the needs of both animal and human population with an opportunity for year round maize production in Karnataka (Table 3). The results of last four years indicated that QPM and other bio-fortified maize hybrids equally yield better or comparable with non QPM maize hybrids in the state (Mahadevu *et al.,* 2020).

Industrial utilities of maize in the region

Maize can be processed into a variety of food and industrial products, including starch, sweeteners, oil, beverages, glue and fuel ethanol. The seeds and cobs are used as the basic raw material in various industries. The seeds are processed and converted into preparations of flour, flakes, grits and pops for human consumption. The shelled cob powder is used as filler in the manufacturing plastics, glues, rayon, resin, vinegar, artificial leather, diluents and carrier in insecticide and pesticide formulations. Based on the chemical properties the processed cobs find their use in the manufacture of alcohols, fermentable sugars, solvents, liquid fuels, charcoal gas and other chemicals by destructive distillation, and also in the manufacture of pulp, paper and hard cardboards. The water soaked with maize grains to produce glucose is used for culturing penicillin moulds. Maize is used extensively in manufacturing of starch, syrup, dextrose, oil, gelatin, lactic and etc. maize flour is used as thickening agent in the preparation of soups sauce custard power and other confectionary preparations. An innovative model has been established for Maize value chain development on commercial scale by farming maize growers federation in Karnataka (Raghupathi *et al.,* 2012)

Major issues in enhancing maize productivity in the state

- Need for development of hybrids with high genetic potential and multiple stress tolerance with wide adaptability for long term sustenance and reduced cost of production (Geeta *et al.,* 2018).

Table 2. Feed and fodder scenario in the state

Area under different forage crops in Karnataka				
Season	Major crops	Varieties/ Hybrid	Area (lakh ha)	
			Irrigated	Rainfed
Kharif	Sorghum	Local/SSG 898	0.16	0.85
	Maize	African Tall/ hybrid Babycorn/ sweet corn	1.01	0.43
	Bajra	Local/ HYV/hybrid	0.25	0.45
	Cowpea/Field bean/Velvetbean /Horsegram	Local/ KBC2/ MFC-08-14/MFC 09-1/ Local	0.20	0.85
Round the year-	Napier Bajra Hybrid	NB-21, Co-3, BH -18, BNH 10, Co 4, BH 9	1.00	-
Perennials	Guinea grass	Macuini, DGG1, JHGG 08-1Reversedale	0.10	-
Rabi	Sorghum	Local/ HYV/hybrid/Dual types	0.28	0.30
	Lucerne	T-9/RL 88	0.10	0.03
	Maize	African Tall/ Local/ Babycorn/ sweet corn	0.25	0.13
Summer	Maize/sorghum/Bajra	HVY/Local/ hybrid/ Babycorn/ sweet corn	0.20	-
		Total	3.55	3.04
		Grand Total	6.59	

Table 3. Performance of Quality Protein Maize hybrids in comparison with normal maize hybrids over the years in southern Karnataka

HQPM Series	2015-16	2016-17	2017-18	2018-19	Mean Grain yield (kg/ha)
HQPM-1	7671	9428	6666	7014	7490
HQPM-4	8473	9419	8091	-	8583
HQPM-5	8585	9414	7937	8047	8367
HQPM -7	**9115**	**10184**	**8040**	**8798**	**9034**
MAH-14-5	-	-	-	8396	8396
Vivek QPM-9	8026	8118	5425	-	7204
MAH-14-5	-	-	-	-	8396
Hema (NAH-1137) (LC)	8622	8438	-	-	8533
General mean	8349	9109	6650	8335	
C.D (5%)	698	840	1616	1773	
C.V (%)	5.1	5.63	14.9	12.95	

- Maize is occupying majority of rice, cotton tobacco area which requires efficient agronomic management soil health for sustainable maize production and productivity.
- Maize may bring less crop diversification due to replacement of many alternative food and fodder crops through monoculturing. It needs promotion of maize and legume based cropping systems for sustainability (Lingaraju *et al.,* 2008).
- Precise management of nutrients water and other agronomic practices for achieving higher productivity through efficient and cost effective hybrids.
- Need for promotion of specialty maize types- sweet corn, baby corn, pop corn, QPM maize, high oil corn etc. for emerging domestic and foreign markets with enormous processing and export potential and play an important dual role, as food and fodder, generating higher income to the farmers (Murida *et al.,* 2016).
- Maize is a viable alternative for Rice, Tobacco, Cotton as semi irrigated short duration crop in command areas which reduces pressure on drinking water needs in water scarcity regions of south India
- Scope for well established referred laboratory for testing quality parameters for high end market of popping, baby corn and sweet corn for processing and export.
- Potentiality for QPM maize is greater in poultry and animal feed industry with strong research & development support in Karnataka.
- Major poultry and cattle feed companies (Suguna, sujay Vencobb, Hatchared, Cargil, CP Godrej, Komarla, Nandi Feeds Karnataka Milk federation) are located in southern Karnataka.
- Fresh baby corn and sweet corn exporters of the country have production and processing plants in Bengaluru and Mysuru regions of the state.
- Large number of stake holders which include around 200 private seed & feed companies, maize based starch industries fresh corn & process corn exporting industries apart from more than 12.0 million maize farmers of the region.
- Many organized poultry farms and processing plants in southern states kept high demand for maize as chief ingredient and correspondingly many poultry and animal feed plants are important buyers of bulk maize in south India with more than 2.0 lakh birds per hour processing capacity.
- Different maize types like popcorn, baby corn, sweet corn, QPM corn, high oil corn need a distinct production, harvesting, processing, value addition and supply chain which can be incorporated in cluster production and backward & forward linkage platforms for ensuring better price to the maize growers as well as consumers.

Acknowledgement

AICRP Forage Crops & Utilization, AICRP Maize (ICAR-New Delhi) and UAS, Bengaluru

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Maize Journal (October 2020) 9(2): 71-80

RESEARCH PAPER

Morphological characterization of maize inbred lines for genetic diversity studies

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Abstract: Maize (*Zea mays* L.) is an important and emerging multipurpose food and feed crop across the world. In context to qualitative and quantitative characters, maize showed wide genetic diversity under varied environments and provides opportunity to exploit it in crop improvement 0. The current study carried out to evaluate morphological variability in 96 maize inbred lines that were developed and maintained at the AICRP on Maize, MMRS, Anand Agricultural University, Godhra, Gujarat during 2012-16. The experiments conducted at the Research Farm, AAU, Anand during *rabi* 2016 and *kharif* 2017. The inbred lines were characterized according to DUS parameters of PPV & FR Act 2004 for 31 morphological traits in randomized block design. The assessment of genetic variability among the inbreds was done by using cluster analysis. It grouped in 6 and 7 clusters in respective environments. Based on different qualitative traits, it included nearly similar set of inbreds in these cluster. Thus, the present investigation revealed that the presence of wide potential genetic diversity among the maize inbred lines under study. The promising inbreds may be used to develop high yield potential and abiotic stress tolerant hybrids for rainfed agro-ecology situations.

Keywords: Cluster analysis · Genetic diversity · Maize · Variability

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Received: 31 July 2020/ Accepted: 15 October 2020

Introduction

Maize (*Zea mays* L.) is an important cereal crop after rice and wheat in India. Being a highest yield potential among cereals, it is known as queen of cereals. On account of broad genetic diversity, it cultivates in wide range of environments. It serves as an ingredient and basic raw materials to thousands of industrial products like, starch, protein, oil, food sweeteners, alcoholic beverages, cosmetic, pharmaceutical, film, gum, textile, package and paper industries etc. (Maize Farmer *Portal:farmer.gov.in/cropstaticsmaize.html*). In the present era, the high yield potential maize hybrids coupled with biotic and abiotic tolerance and biofortification are more preferred by the farmers. The morphological characterization has an important role in the management and conservation of genetic resources as it provides a baseline information regarding the morphological and agronomic traits (Ngwadla, 2002). Presently, many new tools are available to study relationship among the cultivars and different molecular markers. However, morphological characterization is the first step in the description and classification. Several workers have used seed characters for distinguishing varieties of different crops (Burbridge, 1986, Agarwal, 1990). DUS testing is an important method to test inbred lines for distinctness, uniformity and stability (Dhillon *et al.*, 2006) and important prerequisite for granting Plant Breeders Rights (PBR). It is conducted according to national guidelines prepared on the basis of UPOV (The International Union for the Protection of New Varieties of Plants) guidelines. Thus, the present study "Morphological characterization of 96 maize inbred lines for genetic diversity studies" carried out at the Department of Genetics and Plant Breeding, Agronomy Research Farm, BACA, AAU, Anand and AICRP on Maize, MMRS, AAU, Godhra.

Materials and methods

The seeds of 96 inbred lines including white and yellow (Table 1) were obtained from the AICRP on Maize, Main Maize Research Station, AAU, Godhra in *rabi* 2015-16 and maintained at Research Farm, Department of Agriculture Biotechnology in *kharif* 2016 for experimentation.

The Ninety six maize inbred lines were raised in a Randomized Block Design (RBD) in 4 rows of 6m length with the spacing of 75 × 20 cm as inter and intra row spacing with two replications. The experiment was conducted as per the National Test Guidelines for DUS laid by Protection of Plant Varieties and Farmers' Rights Authority (Anonymous, 2007) during *rabi* 2016-17 and *kharif* 2017 at Research Farm, Department of Genetics & Plant Breeding, BACA, AAU, Anand. The all recommended cultivation practices of maize were followed to raise crop for getting the standard phenotypic expressions in the respective environments. The morphological characters were observed and recorded at recommended crop growth stages (Anonymous, 2007). The cluster analysis based on morphological characters was done by using the *XL-Stat 2018 Software*. Agglomerative hierarchical clustering by *Wards Method* was used to construct dendrogram. Genetic dissimilarity among 96 maize inbred lines and distance between clusters were calculated by *Euclidian Distance Method*.

Result and discussion

The inbred lines were showing high variability for all the traits. The detailed characterization of all morphological characters for both seasons for maize inbred are given below.

Morphological characterization according to DUS parameters (rabi 2016)

The 96 maize inbred lines were evaluated for 31 DUS parameters in *rabi* 2016. Among 96 inbred lines, 66 and 30 showed small and wide leaf angles, respectively. The straight leaf blade attitude observed in 64 inbred lines, while, it was drooping in 32 inbred lines. Stem anthocyanin colouration found absent in 75 and was present in 21 inbred lines. Wide range of variations observed for time of anthesis in 96 inbred lines, of which 8, 38, 40 and 10 inbred lines showed very early, early,

Table 1. List of 96 maize inbreds used as experiment material

S.No.	Inbreds	Source	Grain Colour
1	IGI-1602	CML-176	White
2	IGI-1604	CML-186	White
3	IGI-1102	CML-251	White
4	IGI-1606	CML-260	White
5	IGI-1608	CML-264	White
6	IGI-1610	CML-292	White
7	IGI-1612	CML-293	White
8	IGI-1614	CML-490	White
9	IGI-1616	GWL-01	White
10	IGI-1106	GWL-02	White
11	IGI-1618	GWL-03	White
12	IGI-1620	GWL-04	White
13	IGI-1622	GWL-05	White
14	IGI-1624	GWL-07	White
15	IGI-1626	GWL-08	White
16	IGI-1628	GWL-09	White
17	IGI-1104	GWL-10	White
18	IGI-1630	GWL-11	White
19	IGI-1106	GWL-12	White
20	IGI-1632	GWL-13	White
21	IGI-1634	GWL-14	White
22	IGI-1636	GWL-15	White
23	IGI-1638	GWL-16	White
24	IGI-1640	GWL-17	White
25	IGI-1642	GWL-22	White
26	IGI-1644	GWL-24	White
27	IGI-1108	GWL-27	White
28	IGI-1646	GWL-28	White
29	IGI-1648	D-822	White
30	IGI-1652	I-0728	White
31	IGI-16125	LTP-1	Yellow
32	IGI-1601	CML-269	Yellow
33	IGI-1603	CML-296	Yellow
34	IGI-1605	CML-298	Yellow
35	IGI-1101	CML-307	Yellow
36	IGI-1607	CML-482	Yellow
37	IGI-1609	CML-444	Yellow
38	IGI-1611	CML-427	Yellow
39	IGI-16131	CML-104	Yellow
40	IGI-1615	CLQ-30	Yellow
41	IGI-16147	HKI-488-E-4	Yellow

Table 1 contd...

S.No.	Inbreds	Source	Grain Colour
42	IGI-1619	CM-111	Yellow
43	IGI-1621	CM-116	Yellow
44	IGI-1623	CM-123	Yellow
45	IGI-1625	CM-128	Yellow
46	IGI-16137	LM-13-3	Yellow
47	IGI-1629	CM-136	Yellow
48	IGI-1631	CM-137	Yellow
49	IGI-1633	CM-140	Yellow
50	IGI-1635	CM-153	Yellow
51	IGI-1637	CM-212	Yellow
52	IGI-1639	CM-500-1	Yellow
53	IGI-1641	GYL-1	Yellow
54	IGI-1643	GYL -2	Yellow
55	IGI-1645	GYL -4	Yellow
56	IGI-16139	LM-13-4	Yellow
57	IGI-1649	GLY-6	Yellow
58	IGI-1651	GLY-7	Yellow
59	IGI-16133	CM-212-1	Yellow
60	IGI-1655	GYL -9	Yellow
61	IGI-1657	GYL -10	Yellow
62	IGI-1103	GYL -11	Yellow
63	IGI-1659	GYL -12	Yellow
64	IGI-1661	LM-3	Yellow
65	IGI-1663	LM-13-1	Yellow
66	IGI-1665	ITINA-0-11-02	Yellow
67	IGI-1666	ITINA-0-11-03	Yellow
68	IGI-1667	I-07-4-1	Yellow
69	IGI-1669	I-07-5-2	Yellow
70	IGI-1671	I-07-5-1	Yellow
71	IGI-16135	CM-212-2	Yellow
72	IGI-1675	I-07-5-8	Yellow
73	IGI-1677	I-07-5-9	Yellow
74	IGI-1679	I -07-6-1	Yellow
75	IGI-1681	I-07-6-2	Yellow
76	IGI-1683	I-07-6-9	Yellow
77	IGI-1685	I-07-8-6	Yellow
78	IGI-1687	I-07-10-3	Yellow
79	IGI-1689	I-07-10-4	Yellow
80	IGI-1691	I-07-10-5	Yellow
81	IGI-1693	I-07-12-1	Yellow
82	IGI-1695	I-07-54-2	Yellow

Table 1 contd...

S.No.	Inbreds	Source	Grain Colour
83	IGI-16127	LTP-1-1	Yellow
84	IGI-1699	I-07-55-3	Yellow
85	IGI-16101	I-07-55-4	Yellow
86	IGI-16103	HKI-163	Yellow
87	IGI-16105	HKI-3-4-8-5ER	Yellow
88	IGI-16107	HKI-193-1	Yellow
89	IGI-16109	HKI-287-2	Yellow
90	IGI-16125	LTP-1	Yellow
91	IGI-16113	HKI-1040-11-1	Yellow
92	IGI-16115	LM-5	Yellow
93	IGI-16117	LM-6	Yellow
94	IGI-16119	NA-1105-1	Yellow
95	IGI-16121	V35 -1-1	Yellow
96	IGI-16123	PFSR-R-1-2	Yellow

medium and late during tasseling, respectively. Tassel anthocyanin colouration at base of gloom and excluding base was absent in 66 and 42 inbred lines and present in 30 and 44 inbred lines, respectively. Anther colouration found absent in all 96 inbred lines. Among 96 inbred lines, 51 and 45 lines showed sparse and dense spikelet intensity respectively. Whereas, 60 and 36 inbred lines expressed wide and narrow tassel angle between main axis and lateral branches, respectively. Tassel attitude of lateral branches observed curved in 69 inbred lines, while it was strongly curved in 22 and straight in 5 inbred lines. Wide range of variations observed for time of silking in 96 inbreds, of which 41, 40, 12 and 3 inbreds showed late, medium, early and very early silk emergence respectively. Silk colouration and leaf sheath anthocyanin colouration found absent in 92 and 94 inbreds, while it was present in 4 and 2 inbred lines, respectively. About 62 inbreds showed long tassel length and 34 inbreds observed medium length of tassel. The plant height for 96 inbreds found in 3 groups *i.e.* short (40), medium (35) and long (21). Ninety four inbreds showed medium ear placement whereas, remaining 2 inbreds expressed low site of ear placement on plant. In 96 inbreds also found Leaf width in 3 groups, *viz.* narrow (22), medium (43) and broad (31). Ear length observed medium *i.e.* 10-15 cm in 53 inbreds, while, it was long i.e. > 15cm in 43 inbreds. Ear diameter was found large (> 5cm) in all the 96 inbreds. Ear shape was conical in 91 inbred lines, while it was conical-cylindrical and cylindrical in 2 and 3 inbreds respectively. Out of 96 inbreds, 27 showed many (>14) rows of kernel per cob whereas, 69 inbreds expressed medium (10-12) kernel rows. Flint and semi flint/ dent kernel type observed in 90 and 6 inbred lines, respectively. Four types of kernel colour was found in 96 inbreds *viz.*, 56 yellow, 30 white, 6 orange and 4 yellow with white cap. All the 96 inbreds showed white glum colour of cob. Kernel row arrangement was straight, spiral and irregular in 86, 9 and 1 inbreds respectively. All the 96 inbreds showed absent status for kernel poppiness, sweetness, waxiness and opaqueness. Kernel shape was found round in 88 inbreds and indented in 8 inbreds. About 85 inbreds showed medium (200-300gm) weight per 1000 kernel, while 10 inbreds observed small (100-200gm) per 1000 kernel weight.

Morphological characterization according to DUS parameters (kharif 2017)

DUS characterization for 31 morphological parameters was also carried out in *kharif* 2017. Most of the parameters showed similar DUS observation as recorded in *rabi* 2016 for 96 maize inbred lines. These include, leaf angle, leaf blade attitude, stem and tassel anthocyanin colouration, tassel glum and anther colouration, density of spikelet, tassel angle and attitude, silk and leaf sheath anthocyanin colouration, plant ear placement, ear width, ear shape, kernel type and colour, glum colour, kernel row arrangement, kernel poppiness, sweetness, waxiness, opaqueness and kernel shape. While, the characters; tassel time of anthesis, time of silk emergence, tassel length, plant height, leaf width, ear length, number of kernel, rows 1000 seed weight recorded different observations than the season *rabi* 2016. Wide variability observed for tassel time of anthesis in 96 inbred lines, of which 45, 38, 8 and 5 showed medium, early, very early and late time duration for days to 50% anthesis respectively. Whereas, 51, 37, 7 and 1 inbred lines observed medium, early, late and very early duration for days to 50% silking, respectively. Variation was also observed for tassel length, as it was longer in 46, medium in 30 and shorter in 20 inbreds when compared to *rabi* 2016 environment. Wide variation was also found in plant height when compared to *rabi* 2016 environment. The 89 inbreds showed short plant height and 7 inbreds expressed medium plant height. The 47, 28 and 21 inbred lines found medium, narrow and broad leaf width, respectively. Eighty seven inbreds showed medium ear length (10-15 cm), while, rest of 5 and 4 lines observed short and long ear length, respectively. For the character number of kernel rows per cob, about 86 inbreds had medium (10-12) ear rows and 8 and 2 inbreds had many (>14) and few (< 8) rows of kernel per cob. About 44 inbreds had medium (200-300 gm) weight per 1000 kernel, while 52 inbreds had small (100-200 gm) per 1000 kernel weight.

Cluster analysis for DUS parameters in rabi 2016

The dendrogram obtained based on the analysis of morphological characters of all the 96 maize inbreds is depicted in the Figure 1. It was obtained based on agglomerative hierarchical clustering performed on the Euclidean distance matrix utilizing the Ward's linkage method. Genetic dissimilarity coefficient ranged from 1.620 to 13.816. The cluster analysis on qualitative traits resulted in grouping of 96 inbreds into six major clusters. The maximum numbers of inbreds were observed in cluster II (61). While, clusters I, III, IV, V and VI were having 23, 2, 4, 3 and 3 inbreds, respectively. The cluster IV had maximum distance with rest of the clusters. The details of clusters grouping pattern and distance between them are given in Table 2 and 3. The contribution of inbreds in each cluster in determining average variability for different morphological traits is given in Table 4. Cluster IV consisted of 4 inbreds, namely, IGI- 1626, IGI-1644, IGI-1616, IGI-1611 distinguished for presence of ear anthocyanin colouration of silk. Cluster VI consisted of IGI-1607, IGI-1603, IGI-1695 which were characterized based on cylindrical ear shape. Cluster III had 2 inbreds; IGI- 1604 and IGI-1614, both showed wide leaf angle and broad leaf width. Cluster V had IGI-1101, IGI- 1136, IGI-1619 which showed unique character, i.e. semi-flint type of ear grain. Cluster I (23) was supposed to be based on white kernel colour. Cluster II had maximum (64) number of inbreds, which consist of inbreds with various other qualitative characteristics like stem anthocyanin colouration, spikelet density (sparce), plant height (short), conical ear shape and yellow grain. The sister inbreds IGI-16108 and IGI -1609 were categorized into cluster II and cluster I, respectively, based on time of tasseling (late/ medium) and silking (early/ Late).

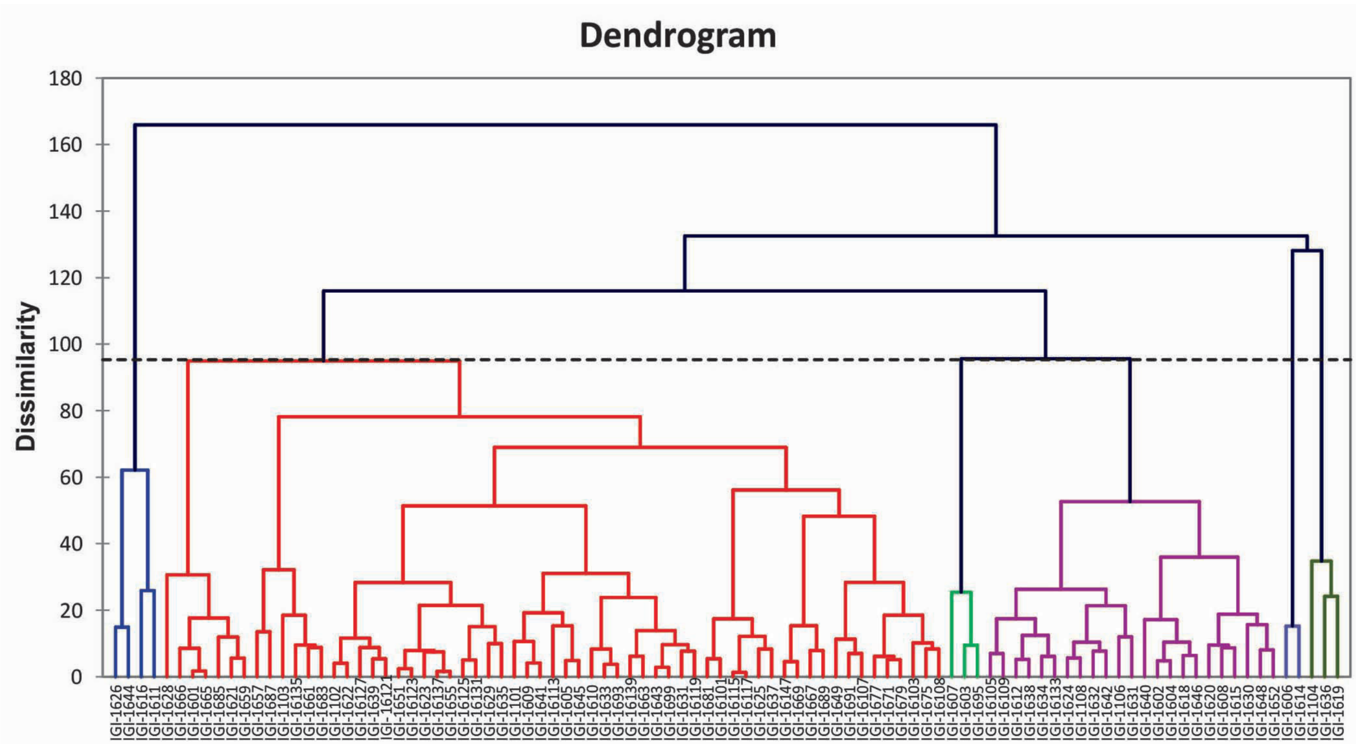

Figure 1. Dendrogram showing relationship among ninety six maize inbreds for morphological traits based on DUS parameters for the season rabi 2016

Table 2. Clustering pattern for qualitative traits in 96 maize inbreds according on DUS parameters (*rabi* 2016)

Cluster No.	No. of inbreds	Name of inbreds
I	23	IGI- 16015, IGI-16109, IGI-1612, IGI-1638, IGI-1634, IGI-16133, IGI-1624, IGI-1108, IGI-1632, IGI- 1642, IGI- 1106, IGI-1631, IGI- 1640, IGI-1602, IGI-1604, IGI-1618, IGI-1646, IGI-1620, IGI-1608, IGI-1615, IGI-1630, IGI-1648, IGI-1652.
II	61	IGI-1628,IGI-1666, IGI-1601, IGI-1665, IGI-1685, IGI-1624,IGI-1659, IGI-1657, IGI-1687, IGI-1103, IGI-16135,IGI-1661, IGI-1683, IGI-1102, IGI-1622, IGI- 16127, IGI-1639, IGI-16121, IGI-1651, IGI-16123, IGI-1623, IGI-16137, IGI-1655, IGI-16125, IGI-16131, IGI-1629, IGI-1635, IGI-1101, IGI-1609, IGI-1641, IGI-16113, IGI-1605, IGI-1645, IGI-1610, IGI-1633, IGI-1693, IGI-16139, IGI-1663, IGI-1643, IGI-1699, IGI-1631, IGI-16119, IGI-1681, IGI-16101, IGI-16115, IGI-16117, IGI-1625, IGI-1637, IGI-16147, IGI-1669, IGI-1667, IGI- 1689, IGI-1649, IGI-1691, IGI-16107, IGI-1677, IGI-1671, IGI-1679, IGI-16103, IGI-1675, IGI-16108
III	2	IGI- 1604, IGI-1614
IV	4	IGI- 1626, IGI-1644, IGI-1616, IGI-1611
V	3	IGI-1101, IGI-1136, IGI-1619
VI	3	IGI-1607, IGI-1603, IGI-1695

Table 3. Distance between cluster centroids (DUS parameters *rabi* 2016)

Clusters	I	II	III	IV	V	VI
I	-					
II	4.528	-				
III	6.939	9.446	-			
IV	10.005	10.388	11.940	-		
V	5.728	5.765	8.838	12.042	-	
VI	6.144	5.036	9.615	11.875	8.212	-

Table 4. Contribution of inbreds in each cluster determining variability in 31 DUS parameters (*rabi* 2016).

Clusters	LA	LAB	SAC	TTA	TACGB	TACEB	TACA	TDS	TAMALB	TALB	ETS
I	4.739	3.435	4.826	3.348	2.739	4.478	1.000	4.580	4.913	5.696	5.522
II	3.984	3.885	1.787	4.508	3.885	5.984	1.000	5.160	5.557	5.787	5.426
III	7.000	1.000	5.000	1.000	1.000	1.000	1.000	7.000	7.000	5.000	6.000
IV	5.000	3.000	5.000	3.500	5.000	5.000	1.000	6.312	7.000	8.000	6.500
V	3.000	1.000	3.667	4.333	1.000	6.333	1.000	7.000	5.667	3.667	4.333
VI	4.333	6.333	1.000	3.667	3.667	3.667	1.000	6.450	5.667	3.667	6.333

Clusters	ESAC	LSAC	TLMA	PH	PEP	LWB	ELWH	EDWH	ES	GR	ETG
I	1.000	1.000	6.217	4.043	5.000	4.739	5.087	7.000	1.000	5.087	1.000
II	1.000	1.000	6.279	4.770	5.000	5.426	6.246	7.000	1.016	5.623	1.000
III	1.000	1.000	7.000	5.000	3.000	4.000	6.000	7.000	1.000	7.000	1.000
IV	9.000	5.000	6.500	4.500	5.000	4.000	6.500	7.000	1.000	6.000	1.000
V	1.000	1.000	6.333	5.667	5.000	6.333	5.000	7.000	1.333	6.333	2.000
VI	1.000	1.000	6.333	4.333	5.000	4.333	5.000	7.000	3.000	5.667	1.000

Clusters	ECTG	EAGC	KRA	KP	KS	KW	KO	KS	KSW
I	1.348	1.000	1.000	1.000	1.000	1.000	1.000	2.000	4.826
II	2.918	1.000	1.164	1.000	1.000	1.000	1.000	2.098	4.836
III	1.000	1.000	1.000	1.000	1.000	1.000	1.000	2.000	4.000
IV	1.500	1.000	1.250	1.000	1.000	1.000	1.000	2.000	5.000
V	2.000	1.000	1.000	1.000	1.000	1.000	1.000	2.667	4.333
VI	3.000	1.000	1.000	1.000	1.000	1.000	1.000	2.000	4.333

LA: Leaf angle, **LAB**: Leaf blade attitude, **SAC**: Stem anthocynin colouration, **TTA:** Tassel anthocynin colouration, **TACGB:** Tassel anthocynin colouration glum base **TACEB**: Tassel anthocynin colouration excluding base of glum, **TACA:** Tassel anthocynin colour of anther, **TDS:** Tassel density of spikelet, **TAMALB:** tassel angle b/w main axis & lateral branch, **TALB:** Tassel attitude of lateral branch, **ETS:** Ear time of silk, **ESAC:** Ear silk anthocynin colouration, **LSAC:** Leaf sheath anthocynin colouration, TLMA: Tassel length above main axis, **PH:** Plant height, **PEP:** Plant ear placement, **LWB:** Leaf width of blade, **EL:** Ear length, **EW:** Ear Width, **ES:** Ear Shape, **GR:** Ear grain row, **ETG:** Ear type of grain, **ECTG:** Ear colour of top grain, **EAGC:** Ear anthocynin glum colour, **KRA:** Kernel row arrangement, **KP:** Kernel poppiness, **KS:** Kernel sweetness, **KW:** Kernel waxiness, **KO:** Kernel opaqueness, **KS:** kernel shape and **KSW:** Kernel seed weight

Cluster analysis for DUS parameters in kharif 2017

In *kharif* 2017, cluster analysis for 31 DUS parameters in 96 inbreds, formed 7 major clusters. Genetic dissimilarity coefficient ranged from 2.080 to 13.278. The details of clusters grouping pattern and distance between them and contribution of inbreds in each cluster in determining average variability for different morphological traits is given in Table 5-7. The dendrogram obtained based on the analysis of morphological characters of all the 96 maize inbreds is depicted in the Figure 2. Cluster IV consisted of similar set of inbreds (IGI- 1626, IGI- 1644, IGI- 1616, IGI-1611), based on presence of ear anthocyanin colouration of silk, which was observed for *rabi* 2016 season. Similarly, Cluster II and VI were found to consist of almost same set of inbreds as observed in Cluster II and I of *rabi* 2016. Cluster VI had 2 minor cluster, of which IGI-1607, IGI- 1603 and IGI-1695 which were characterized based on cylindrical ear shape, while another minor cluster consisted of 4 inbreds IGI-1687, IGI-16139, IGI-16131 and IGI-1649 having broad leaf width. The sister lines IGI-1665 and IGI-1666 grouped in to Cluster II and VII based on number of rows (medium and many, respectively). Inbred IGI-1625 and IGI-1637 from cluster II separately formed sub cluster based on spiral kernel row arrangement. Some inbreds having medium and late ear silking time grouped in cluster I. Majority of white grain inbreds falls in cluster I. The Inbreds IGI-1611 and IGI-1616 from cluster IV showed maximum Euclidian distance with other Inbreds.

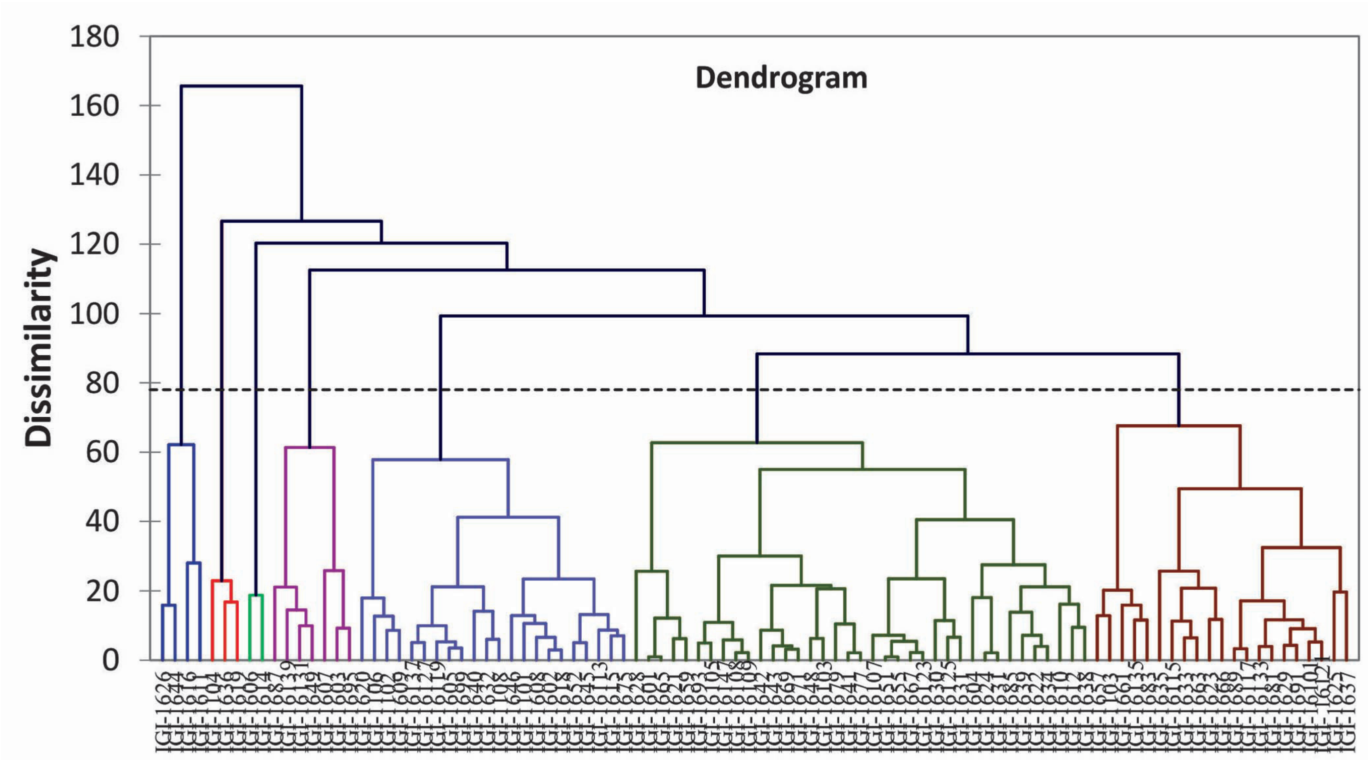

Figure **2.** Dendrogram showing relationship among ninety six maize inbreds for morphological traits based on DUS parameters for the season *kharif* 2017

Table 5. Clustering pattern for qualitative traits in 96 maize inbreds according on DUS parameters for the season *kharif* 2017

Cluster No.	No. of inbreds	Name of inbreds
I	22	IGI-1620, IGI-1106, IGI-1102, IGI-1609, IGI-16137, IGI-16127, IGI-16119, IGI-1605, IGI-1699, IGI-1640, IGI-1632, IGI-1108, IGI-1646, IGI-1101, IGI-1608, IGI-1602, IGI-1618, IGI-1652, IGI-1645, IGI- 16113, IGI- 1615, IGI- 1675
II	37	IGI- 1628, IGI-1601, IGI-1665, IGI-1621, IGI-1659, IGI-1693. IGI-16105, IGI-16147, IGI-16108, IGI-16109, IGI-1642, IGI-1643, IGI-1669, IGI-1671, IGI-1648, IGI-16103, IGI- 1679, IGI-1641, IGI-1677, IGI-16107, IGI-1651, IGI-1655, IGI-1667, IGI-16123, IGI-1630, IGI-16125, IGI-1631, IGI-1604, IGI-1624. IGI-1631, IGI-1685, IGI-1639, IGI-1622, IGI-1634, IGI-1610, IGI-1612, IGI-1638.
III	2	IGI-1606, IGI-1614
IV	4	IGI- 1626, IGI- 1644, IGI- 1616, IGI-1611
V	3	IGI- 1104, IGI-1639, IGI-1619
VI	7	IGI-1687, IGI-16139, IGI-16131, IGI-1649, IGI-1607, IGI-1603, IGI-1695.
VII	21	IGI-1657, IGI-1103, IGI-1661, IGI-16135, IGI-1683, IGI-1635, IGI-16115, IGI-1633, IGI-1663, IGI-1623, IGI-1666, IGI-1689, IGI-16117, IGI-16133, IGI-1681, IGI-1629, IGI-1691, IGI-16101, IGI-16121, IGI-1625, IGI-1637.

Table 6. Distance between cluster centroids (DUS Parameters *kharif* 2017)

Clusters	I	II	III	IV	V	VI	VII
I	-						
II	4.835	-					
III	8.179	8.075	-				
IV	10.283	10.511	11.622	-			
V	6.561	4.888	8.048	11.797	-		
VI	5.668	4.020	7.973	11.628	6.486	-	
VII	5.944	3.999	8.960	10.002	7.256	5.684	-

Table 7. Contribution of inbreds in each cluster determining variability in 31 DUS parameters in *kharif* 2017.

Clusters	LA	LAB	SAC	TTA	TACGB	TACEB	TACA	TDS	TAMALB	TALB	ETS
I	3.364	5.364	4.636	5.273	2.091	5.727	1.000	4.850	5.545	5.909	5.364
II	4.405	3.595	2.081	3.000	3.595	5.541	1.000	5.412	4.838	5.108	3.541
III	7.000	1.000	5.000	4.000	1.000	1.000	1.000	7.000	7.000	5.000	5.000
IV	5.000	3.000	5.000	4.500	5.000	5.000	1.000	7.000	7.000	8.000	5.000
V	3.000	1.000	3.667	2.333	1.000	6.333	1.000	4.517	5.667	3.667	3.000
VI	5.286	4.429	1.000	4.143	2.143	4.429	1.000	5.680	5.857	3.857	4.429
VII	4.333	2.524	1.762	4.429	5.571	5.571	1.000	7.000	6.048	7.095	4.619

Clusters	ESAC	LSAC	TLMA	PH	PEP	LWB	ELWH	EDWH	ES	GR	ETG
I	1.000	1.000	6.364	3.000	5.000	4.545	4.636	7.000	1.000	5.000	1.000
II	1.000	1.000	6.135	3.054	5.000	4.568	5.000	7.000	1.000	5.000	1.000
III	1.000	1.000	7.000	3.000	3.000	4.000	4.000	7.000	1.000	5.000	1.000
IV	9.000	5.000	6.500	3.000	5.000	4.000	5.000	7.000	1.000	4.500	1.000
V	1.000	1.000	6.333	3.000	5.000	4.333	5.000	7.000	1.333	5.000	2.000
VI	1.000	1.000	6.143	4.429	5.000	5.857	5.000	7.000	2.000	5.000	1.000
VII	1.000	1.000	6.429	3.095	5.000	5.571	5.190	7.000	1.000	5.667	1.000

Clusters	ECTG	EAGC	KRA	KP	KS	KW	KO	KS	KSW
I	2.045	1.000	1.000	1.000	1.000	1.000	1.000	2.000	4.273
II	2.351	1.000	1.189	1.000	1.000	1.000	1.000	2.000	3.649
III	1.000	1.000	1.000	1.000	1.000	1.000	1.000	2.000	4.000
IV	1.500	1.000	1.250	1.000	1.000	1.000	1.000	2.000	4.000
V	2.000	1.000	1.000	1.000	1.000	1.000	1.000	2.667	3.667
VI	3.143	1.000	1.000	1.000	1.000	1.000	1.000	2.143	4.143
VII	3.048	1.000	1.143	1.000	1.000	1.000	1.000	2.238	3.952

LA: Leaf angle, **LAB:** Leaf blade attitude, **SAC:** Stem anthocyanin colouration, **TTA:** Tassel anthocyanin colouration, **TACGB:** Tassel anthocyanincolourationglumbase,**TACEB:**Tasselanthocyanincolouration excluding base of glum, **TACA:** Tassel anthocyanin colour of anther, **TDS:** Tassel density of spikelet, **TAMALB:** tassel angle b/w main axis & lateral branch, **TALB:** Tassel attitude of lateral branch, **ETS:** Ear time of silk, **ESAC:** Ear silk anthocyanin colouration, **LSAC:** Leaf sheath anthocyanin colouration, **TLMA:** Tassel length above main axis, **PH:** Plant height, **PEP:** Plant ear placement, LWB: Leaf width of blade, **EL:** Ear length, **EW:** Ear Width, **ES:** Ear Shape, **GR:** Ear grain row, **ETG:** Ear type of grain, **ECTG:** Ear colour of top grain, **EAGC:** Ear anthocynin glum colour, **KRA:** Kernel row arrangement, **KP:** Kernel poppiness, **KS:** Kernel sweetness, **KW:** Kernel waxiness, **KO:** Kernel opaqueness**, KS:** kernel shape and **KSW:** Kernel seed weight.

Thus the cluster analysis of ninety six maize inbreds for 31 DUS parameters forms 6 and 7 clusters in *rabi* 2016 and *kharif* 2017, respectively. Based on presence of ear anthocyanin colouration of silk, similar set of inbreds (IGI- 1626, IGI- 1644, IGI- 1616, IGI-1611), was observed in both *rabi* 2016 and *kharif* 2017 seasons. Most of the parameters showed similar DUS observation for both the season. The qualitative characters like leaf angle, leaf blade attitude, stem anthocyanin colour, tassel anthocynin colour of glum at base and excluding base, tassel angle and attitude of lateral branches, anthocynin colouration of ear silk, leaf sheath colouration, spikelet density, tassel length, plant ear placement, ear shape, ear grain type and grain top colour, kernel row arrangement, kernel shape were showed similar notations in all the inbreds in both the seasons. While the characteristics like anther colour, ear diameter, ear anthocyanin colour of glum of cob, ear waxiness, poppiness, sweetness and opaqueness were similar for all the 96 inbreds. From data on both the season, it was observed that, qualitative characters remain unaffected in changing environmental conditions. In present research, the results on DUS parameters by cluster analysis showed significant variability in 96 maize inbreds for qualitative traits based on single or multiple specific characters that can be utilized in selecting inbreds in different maize breeding programme for further crop improvement.

Similar kind of maize variability was reported in maize inbred lines by Sokolove and Guzhva (1997) and Abidi *et al.* (2019). Abu-Alrub *et al.* (2006) used kernel traits as the best descriptors for classifying Peruvian highland maize germplasm, followed by ear traits and also expressed that tassel traits were found to be less reliable descriptors for classifying the germplasm. Carvalho *et al.* (2004) constructed dendrogram based on genetic similarity using the UPGMA method which grouped 81 maize accessions into two clusters which were correlated according to kernel colours. Hemavathi, (2008) grouped 42 maize inbreds based on the multivariate analysis and revealed that, these genotypes could be grouped into seven clusters and among them, cluster II consisted of 20 inbreds followed by cluster III (7), cluster IV (5), cluster I (3), cluster VII (3) and cluster V and VI had 2 inbreds each respectively. Rahman *et al.* (2008) also grouped the maize populations, based on cluster analysis for morphological and maturity parameters into three main clusters comprising sub-clusters. Ranatunga *et al.* (2009) indicated that cluster analysis using eight different qualitative traits across 43 maize genotypes resulted in grouping of genotypes into two major clusters of 19 and 24 genotypes. Yadav and Singh (2010) evaluated eleven morphological characteristics according to DUS test on 30 maize inbred lines which were divided into three major groups based on dissimilarity matrix analysis, indicating all 30 lines were found to differ from each other. Pinnisch *et al.* (2012) characterized 27 maize inbred lines and suggested that grain yield, thousand-kernel weight, ear length and kernel morphology were the traits suitable for the inbred line to use as a seed parent. Selvi *et al.* (2013) initiated DUS characterization study on 17 maize inbreds divided into 6 clusters based on dissimilarity matrix. Madhukeshwara and Sajjan (2015) analysed of 13 morphometric characterization for 7 genotypes including 2 hybrids revealed that more variation for plant height, tassel attitude, tassel angle, ear shape and thousand seed weight. Sabina N. *et al.* (2018) also studied 19 DUS descriptors on 5 varieties and reported similar scale for the characteristics studied.

Conclusion

Maize *(Zea mays* L.) is the most multipurpose food crop of global importance next to wheat and rice. Maize is grown both as food for human beings and fodder for animals. It is an important source for getting protein and calories and a staple food for several million people in the developing world. Development of high yielding hybrids is the most important goal of any maize breeder to enhance its productivity. For developing hybrids, better pure inbred lines with high mean performance are required. In genetics and breeding for hybrid corn production maize inbred lines represent a fundamental resource for studies (Anderson *et al.*, 1952). The classification and grouping of lines helps the breeders to identify varieties and hybrids. Knowledge of variability and genetic diversity in maize germplasm helps to make sure that a wide genetic base of breeding materials is maintained, for dropping genetic susceptibility to pests and diseases and supporting genetic improvement (Yadav and Singh, 2010). Morphological traits traditionally have been used as descriptors. It is likely that their use will continue because they are omnipresent in agriculture (Smith and Smith, 1989b). The results on DUS parameters by cluster analysis showed significant variability in 96 maize inbreds for qualitative traits based on single or multiple specific characters that can be utilized in selecting inbreds in different maize breeding programme for further crop improvement. The morphological variations existed in inbreds due to variation in genetic makeup and could be better utilized by breeders in the selection of inbreds according to their specific requirement in maize breeding programme. Thus, the present investigation resulted in identification of potential genetic diversity and variability among 96 maize inbreds and information generated through this study can be effectively used in planning maize crop improvement.

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Maize Journal (October 2020) 9(2): 81-86

RESEARCH PAPER

Genetic variability for yield components, starch and oil content in tropical field corn (*Zea mays* L.) germplasm

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Abstract: Understanding the genetic variability is prerequisite for the trait-based crop improvement. Information on variance parameters, heritability and correlation among the traits may be very much useful for the targeted yield enhancement. Biochemical parameters add value to the final product has immense practical utility in maize based industries. A genetic study was conducted at ICAR-Indian Agricultural Research Institute, to identify most promising yield component traits in tropical maize inbreds *visa vis* inbred lines bearing these traits. Total 280 germplasm were subjected to preliminary evaluation and among them, 45 promising lines were selected. These 45 lines were evaluated across three environments. It was observed that environments have less impact on genetic variation of kernel row number, cob length, cob girth, kernel per row and spikelet per tassel and also these traits showed high heritability indicating its additive genetic control. Correlation among yield component traits indicated its possible selection of single or group of traits for the yield enhancement in maize. Biochemical analysis indicated that these selected lines are also good source of starch and oil content and they can also be used as donor for future grain quality improvement program in maize. Total five lines each were selected for productivity (AI 43, AI 27, AI 36, AI 22 and AI 39), oil content (AI 6, AI 32, AI 26, AI 40 and AI 11) and starch content (AI 33, AI 12, AI 44, AI 23 and AI 38). These lines can be used as donor/parental lines in future hybrid breeding/maize improvement program.

Keywords: Kernel row number · Oil · Spikelet · Starch · Variability

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Received: 31 July 2020/ Accepted: 31 October 2020

Introduction

Enhancing grain yields is one of the major targets of plant breeder, which is a toilsome task due to its complexity, determined by component traits and governed by polygene. The effectiveness and success of selection for desirable traits for high yield primarily depends on the nature and extent of genetic variability in the existing germplasm. Understanding of genetic variability present in a given crop species for the traits under improvement is essential for the success of any plant breeding program (Sankar *et al.*, 2006). Efficiency of selection depends on the magnitude of genetic variability present in the plant population. Thus, success of genetic improvement in any character depends on nature of variability present in the germplasm for that character.

Analysis of variability, heritability and genetic advance help to ascertain the real potential value of the genotype. Direct selection is possible and effective for characters with high heritability. However, economically important and polygenic characters like yield generally have low heritability and direct selection is not effective. So, it is desirable to select specific traits indirectly for the purpose of improving yield. Identification of heterotic hybrids can serve as a potential driver to close the productivity and yield gaps. The success in this endeavor depends on the availability of reliable genetic variability among the maize inbred lines.

Grain yield being a quantitative trait and controlled by various quantitative trait loci (QTL)/genes, is affected by various environmental factors (Beavis *et al.*, 1994; Messmer *et al.*, 2009). As a result, this complex trait must be dissected into its related/component traits. Kernel size and kernel weight are the primary yield component traits contributing significantly to final grain yield. These have both direct effect and indirect effect through other yield contributing components such as ear length, kernel row number and kernel number per ear. Further compared to grain yield, these component traits have higher heritability and better stability across the environments. Therefore, understanding of genetic basis of component traits will enhance the efficiency of breeding for grain yield. However, polygenic characters like yield and economically important characters generally have low heritability and direct selection is not effective. Efficiency of selection in any breeding program mainly depends upon the knowledge of association of the characters. Phenotypic correlation indicates the extent of the observation having relation between two characters while genotypic correlation provides an estimate of inherent association between the genes controlling any two characters.

Important Biochemical parameters like starch and oil content add value to the final usage of maize based products. High starch content and kernels with enhanced oil content will fetch premium market price. These traits may in turn be inter-related to kernel morphology. But the genetic information on kernel size and kernel weight and specific utilization of them in breeding program is lacking in the tropical region in general including India. Hence it is required to analyze and understand the genetic variability for these important kernel traitsamong the tropical maize germplasm.

Materials and methods

A set of 280 tropical maize lines were evaluated in augmented design for morpho-phenological traits at Indian Agricultural Research Institute (IARI), New Delhi during *rabi* 2017-18. Among them, 45 genotypes were chosen based on the superior performance for their yield component traits. These selected lines were subjected to comprehensive evaluation across three environments, *viz*., *kharif* 2018 and *rabi* 2018-19 at Indian Agricultural Research Institute (IARI), New Delhi and *rabi* 2018-19 at IARI-Regional Research Centre, Dharwad. The experiment was laid-out in a Randomized Complete Block Design (RCBD) with two replications in all the test environments. The genotypes were allotted randomly within each replication. Each genotype was sown in two rows of three meters length and inter and intra-row spacing of 75 cm and 20 cm, respectively. Recommended package of practices was followed maintaining the satisfactory crop stand and crop growth in all the three environments. Data were recorded on cob length, cob girth, number of kernel rows, kernels per row, kernel size, kernel thickness, rachis, spikelets, test weight and grain yield. The estimation of oil content was done by using Nuclear Magnetic Resonance (NMR) technology. NMR was calibrated by using fresh maize oil extracted through Soxhlet apparatus. Starch content was estimated by enzymatic method using Megazyme's Total Starch HKAssay Kit, (K-TSHK), a modification of AOAC Method. The data obtained by phenotypic evaluation and biochemical estimation were subjected to statistical analysis by using SAS 9.3v (http://sscnars.icar.gov.in/).

Results and discussion

The ANOVA was carried-out in order to partition the total variance into variance due to genotype and other sources of variation for all characters (Table 1). It was revealed that mean sum of square due to inbred lines were significant for all the morphological characters under study, which undoubtedly implies ample amount of variability present among the 45 inbred lines. Since the selected 45 inbred lines are from broad based source population, this variability is expected. The repeatable phenotypic expression over three environments strongly suggests that inbred lines under study can be good source of genetic variation for further maize breeding program.

Yield components

Maize grain yield is dependent on the proper expression of their component traits *viz.*, cob length, cob girth, kernel rows number, kernels per row and other kernel related traits etc. They can be systematically utilized resulting in significant impact on final improvement of maize yield, if selections are trait driven. The cob length (cm) varied from

6.75 to 19.60 with a mean of 12.16; however, cob girth (cm) ranged from 2.05 to 4.75 with overall mean of 3.22. Number of kernel rows/cob (KRN) ranged from 10 to 26 with a mean value of 16. Number of kernels/rows ranged from 11.10 to 32.10 with mean of 22.68. Test weight (100 kernel weight) was 14.85 to 31.95 with mean value of 21.37. Similarly, kernel length (mm) ranged from 7.75 to 11.15 with 9.06 as average. Kernel thickness (mm) varied from5.55 to 8.60 with mean of 6.89. For number of rachis variation was from 6.00 to 29.00 having the mean value of 14.22. For number of spikelet, it ranged from 24.95 to 41.50 with average of 33.39. Grain yield (t/ha) representing productivity potentiality, varied from 1.03 to 3.90 with mean of 3.15 (Table 2). Several researchers such as Abayi *et al*. (2004), Turi *et al*. (2007) and Yusuf (2010) also reported significant variability for these characters under study. Considering the productivity of inbred lines, top five lines *viz*., AI 43 (3.61 t/ha), AI 27 (3.60 t/ha), AI 36 (3.60 t/ha), AI 22 (35.50 t/ha) and AI 39 (3.58 t/ha) were selected for future utilization in hybrid breeding program.

For all the characters, phenotypic variance was higher than the genotypic variance. This can be attributed to non-genetic factors in the manifestation of these characters. High genotypic and phenotypic coefficient of variation were recorded (Table 2) for grain yield (t/ha) indicating their importance in evolution and selection of inbred lines (lyas *et al.*, 2019). Moderate genotypic and phenotypic coefficient of variation was observed for kernel length (KL) and kernel thickness (KT). Comparative values

Table 1. Analysis of variance for yield and yield component traits across three environments

Location	Source	Df	CL	CG	KRN	KPR	TW (100)	KL	KT	Rachis	Spikelet	YLD
E1	Replication	1	0.001	0.001	0.025	3.843	0.038	0.053	0.000	1.573	6.136	0.098
	Treatment	44	15.933**	0.560**	18.624**	42.863**	29.916**	0.7441**	1.052**	47.632**	46.470**	0.902**
E2	Replication	1	0.286	0.001	0.336	2.915	1.045	0.011	0.009	1.803	0.113	0.014
	Treatment	44	15.083**	0.572**	22.273**	38.748**	21.713**	1.1432**	1.445*	98.607**	37.072*	0.854*
E3	Replication	1	0.702	0.069	0.011	9.088	3.520	0.336	0.128	1.296	5.112	0.110
	Treatment	44	12.264**	0.474**	24.604**	41.029**	23.769**	0.8300**	0.875*	50.580**	28.633*	0.535*

KRN-Kernel Row Number, KPR- Kernels per Row, CL -Cob Length, KL – Kernel Length, CG -Cob girth, KT – Kernel Thickness, YLD –Yield, TW – Test Weight, *: Statistically significant at 5% probability, **: Statistically significant at 1% probability
E1*:* *kharif* 2018 at Indian Agricultural Research Institute, New Delhi
E2: *rabi* 2018-19 at Indian Agricultural Research Institute, New Delhi
E3: *rabi* 2018-19 at Regional Research Centre, Dharwad.

Table 2. Genetic variability parameters for yield and yield component traits in field corn inbred lines

Characters	Mean	Range	PCV			GCV			$H^2_{(BS)}$		
			E1	E2	E3	E1	E2	E3	E1	E2	E3
CL (cm)	12.16	6.75 to 19.60	22.80	21.34	20.47	22.43	21.28	98.00	96.7	99.50	98.00
CG (cm)	3.22	2.05 to 4.75	15.01	15.28	15.21	14.46	14.52	97.60	92.8	90.30	97.60
KRN	15.90	10.50 to 24.50	20.06	21.59	22.45	19.99	21.55	93.00	99.4	99.60	93.00
NPR	22.68	11.10 to 32.10	21.55	20.04	20.84	21.00	19.64	83.60	94.9	96.00	83.60
TW (100)	21.37	14.85 to 31.95	18.21	15.89	16.96	17.12	14.63	81.00	88.4	84.90	81.00
KL (mm)	9.06	7.75 to 11.15	7.16	8.58	7.58	6.47	8.29	75.80	81.7	93.20	75.80
KT (mm)	6.89	5.55 to 8.60	11.48	12.29	10.07	9.71	12.06	81.80	71.5	96.40	81.80
YLD (t/ha)	3.15	1.03 to 3.90	24.57	24.62	16.88	24.39	23.61	88.90	98.5	92.00	88.90

KRN-Kernel Row Number, KPR- Kernels per Row, CL -Cob Length, KL – Kernel Length, CG -Cob girth, KT – Kernel Thickness, YLD –Yield, TW – Test Weight
E1*:* *kharif* 2018 at Indian Agricultural Research Institute, New Delhi
E2: *rabi* 2018-19 at Indian Agricultural Research Institute, New Delhi
E3: *rabi* 2018-19 at Regional Research Centre, Dharwad

between GCV and PCV revealed small differences between them suggesting important role of additive gene action operating among the trait under investigation. Therefore, such characters could be relied upon and simple selection can be practiced for the strategy of further improvement (Langade *et al.,* 2013; Prodhan *et al.,* 2007; Murugan *et al.,* 2010; Shanthi *et al.,* 2011; Hepziba *et al.,* 2013).

Heritability is a measure of extent of phenotypic variation attributable to the gene action. It is a good index of the transmission of characters from parents to their offspring (Falconer, 1981). The heritability in broad sense was worked out for all the characters and their performance adjudged on the biometrical basis given by Johnson *et al*. (1955). The higher value of the heritability estimates is advantageous where improvement is sought through phenotypic selection (Bartaula *et al.,* 2009). High heritability of the traits indicates high breeding value which can be utilized to guide a selection program of inbred lines in desirable direction (Abayi *et al.,* 2004; Sumalini and Manjulatha, 2012; Hepziba *et al.,* 2013).

Character association

The knowledge of the nature and magnitude of inter-relationship among yield and its components are very important for the simultaneous improvement of the characters and thus become necessary for effective yield improvement. An understanding of the association between contributing traits and their relative contribution to yield is essential to bring a rational improvement in desirable traits. Falconer (1981) while studying the genetic mechanism of association between two characters suggested that the linear association may be due to complete linkage or pleiotropy. Correlation resulting from linkage or pleiotropy is the overall effect of those genes that affect both the characters. Some gene increases both the characters (positive- correlation), whereas some may increase one character and decrease another character (negative correlation). Cob length is positively associated with number of kernels per row and number of spikelet per tassel (Table 3). Intern number of kernel per row showed positive correlation with spikelet per tassel. Hence selection towards increased cob length and more spikelet per tassel may enhance grain yield as cob length also showed positive association with yield (Saha and Mukherjee, 1993; Hepziba *et al.,* 2013). Cob girth showed positive significant correlation with KRN, test weight, kernel length and yield indicating possible improvement in grain yield by the targeted selection for cob girth in maize. The KRN had negative association with cob length but positive significant correlation with kernel length. This may be because to adjust the given number of kernels in a cob with the reduced cob length by virtue of increased KRN, length of the kernel may increase compromising its thickness (Aman *et al.,* 2020). The kernels per row have showed positive significant correlation with number of spikelet. Test weight is showing positive significant correlation with kernel length, kernel thickness and yield. Kernel length is positively associated with kernel thickness and yield while negatively with number of spikelet. Hence cob length, cob girth, kernel row number and spikelet number were considered as important yield component traits. These component traits may be selected individually or to ensure proper balance among them in combinations

Table 3. Phenotypic correlation among cob and kernel parameters in field corn inbred lines

Traits	CL	CG	KRN	NKPR	TW	KL	KT	Rachis	Spikelet	YLD
CL	1	-0.23	-0.26	0.80**	0.11	-0.12	0.03	0.11	0.31*	0.11
CG		1	0.70**	-0.14	0.54**	0.49**	0.24	-0.14	0.08	0.61**
KRN			1	-0.07	0.17	0.38**	0.06	-0.20	0.15	0.46**
KPR				1	-0.07	0.05	0.06	0.23	0.31*	0.28
TW					1	0.46**	0.35*	-0.17	-0.13	0.40**
KL						1	0.66**	0.06	-0.08	0.43**
KT							1	0.28	-0.11	0.17
Rachis								1	0.22	-0.09
Spikelet									1	0.31*

KRN-Kernel Row Number, KPR- Kernels per Row, CL -Cob Length, KL – Kernel Length, CG -Cob girth, KT – Kernel Thickness, YLD –Yield, TW – Test Weight, *: Statistically significant at 5% probability, **: Statistically significant at 1% probability

Table 4. Performance of field corn inbred lines for their biochemical parameters

S.No	Genotypes	Starch content (%)	Genotypes	Oil content (%)
1.	AI 33	73.83	AI 6	7.61
2.	AI 12	73.46	AI 32	7.43
3.	AI 44	72.13	AI 26	7.21
4.	AI 23	72.11	AI 40	7.01
5.	AI 38	70.98	AI 11	6.99
Mean		63.17		5.40
Range		60.10 to 73.83		2.45 to 7.61
SD		6.53		1.20

for enhancing maize grain yield (Kumar *et al.,* 2006; Jawaharlal *et al*., 2011).

Starch and oil

Production of corn with high starch and oil content is the need of processing industry since it has multiplicative uses along with yield. Therefore, it is highly beneficial to combine these biochemical parameters relating to quality traits with productivity in any selection program. Understanding the available variability for the starch and oil content in maize inbred lines is the basic step for further their targeted improvement. From inbred lines used in this study, it was found that (Table 4), starch content ranged from 60.10 per cent to 73.83 per cent with the mean starch content 63.17 per cent. The population standard deviation for the trait was 6.53. Total starch content the highest value has been observed for the AI 33 (73.83 per cent) followed by AI 12 (73.46 per cent) and lowest starch content was present in AI 35 (60.10 per cent). Similarly, the oil content varied from 2.45 per cent to 7.61 per cent with the mean oil content 5.40 per cent. The population standard deviation for the oil content was 1.20. AI 06 has got highest oil content (7.61 per cent), followed by AI 32 (7.43 per cent), while AI 44 showed lowest oil content of 2.45 per cent. Hence there was an ample scope for selecting promising inbred lines for these two biochemical traits also. Five potential genotypes for high oil (AI 6, AI 32, AI 26, AI 40 and AI 11) and starch content (AI 33, AI 12, AI 44, AI 23 and AI 38) were identified among the set of 45 inbred lines. The selected inbred lines may be re-evaluated for ascertaining the composition of the biochemical traits. After confirming its repetitive expression, these genotypes can be used as parental lines for the development of hybrids aiming to improve starch and oil content in maize.

Conclusion

Understanding of genetic variability and heritability of the traits are basic requirement of any plant breeding intervention to start with the aim of targeted crop improvement. Though the continuous studies on yield component in maize are justified over a period for yield gain, understanding the available variability in the test material always gives new direction for its improvement. Association studies along with the information on heritability will give the opportunity to select combination of traits to be targeted for enhancing yielding ability of the crop. In the present investigation, cob girth, cob length, kernel row number and spikelet were shortlisted as important yield attributing traits. The present study identified inbred lines which were also good source of starch and oil content. The information generated on starch and oil content in the present study, after confirmation, can be further utilized in maize breeding program in general and grain quality improvement in particular.

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Maize Journal (October 2020) 9(2): 87-93

RESEARCH PAPER

Genetic diversity study for useful breeding traits in maize inbred lines using principle component and cluster analysis grown under rainfed condition

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Abstract: Knowledge of genetic diversity is important prerequisite for the development of outstanding hybrids. In the present investigation a total of forty six maize inbred lines were evaluated under rainfed condition. Four phenological traits viz., days to 50% tasseling, days to 50% silking, anthesis silk interval and days to 75% husk maturity, three plant architecture related traits i.e., plant height (cm), ear height (cm) and leaf area (cm^2), five yield related traits viz., 100-seed weight (g), kernel rows per ear, number of kernels per)row and grain yield per plant (g) and three quality traits i.e., protein content (%), starch (%) and zinc content (ppm) using principal component analysis were studied. The PCA identified six principal components (PCs) with Eigen value greater than one and accounted for 76.25 per cent of the total variation. Cluster analysis based on Ward's minimum variance procedure distributed the inbreds into 07 clusters indicating their broad genetic base. Cluster II was the largest containing twelve inbreds followed by cluster VI suggesting their use in breeding programmes for the exploitation of heterosis for the desirable yield traits. Selection of parents from these diverse clusters for hybridization programme would help in achieving heterotic hybrids. The selection from the first and fourth cluster can be considered worthwhile as it has genotypes performing better in terms of yield and yield attributing characters.

Keywords: Principle component · Cluster analysis · *Zea mays* · Quantitative traits

Introduction

Maize (*Zea mays* L.) is one of the most important economic crops that promote global food security (Liyew *et al.*, 2020). It is widely used for food, animal feed, edible oil and fuel worldwide. The plant is native to South America and has chromosome number of 2n = 20. Maize (*Zea mays* L.) is known as golden crop because every part of this crop is useful to man, animals and the industries. Globally, it is the most important cereal food crop after wheat and rice accounting for 9 per cent of the total food grain production. It has occupied a prominent place in Indian agriculture as it is widely grown in India in varied climatic situations throughout the year suggesting its wider adaptability. The major objective of the maize breeding programmes is to develop high yielding hybrids than the existing composites or synthetics as hybrids are popular among the farming community for their yield advantage over the varieties and others. Several studies on maize have shown that inbred lines from diverse stocks tend to be more productive than crosses of inbred lines from same

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Received: 19 August 2020/ Accepted: 20 November 2020

variety (Vasal, 1998). Expression of heterosis usually depends on the genetic divergence of the two parental lines (Saxena *et al.*, 1998). To develop high yielding hybrids in maize, the development and evaluation of inbreds form the major thrust area of the plant breeding programmes. Hence, inbred lines developed through sib mating etc. need to be evaluated for their genetic diversity and performance to plan an effective hybrid breeding programme.

Evaluation, characterization and classification of genotypes based on estimates of genetic diversity will help to identifying diverse parental lines which can be used in hybrid breeding to develop potential hybrids or varieties. The assessment of the diversity and genetic distance in the available maize inbreds is important for a hybrid breeding program, in order to identify inbreds that would produce crosses with high heterotic effect without testing all hybrids combinations Badu *et al*. (2013). Several methods have been reported to decipher the pattern and magnitude of variability such as Mahalanobis D^2 analysis, Principal component analysis and hierarchical cluster analysis based on Ward's minimum variance method. Multivariate analysis based on principal component analysis (PCA) is mostly used to evaluate the magnitude of genetic diversity among the germplasm (Brown Guedira, 2000). Principal component analyses help researchers to distinguish significant relationship between traits. In view of the above, 46 inbred lines were investigated to study the nature and magnitude of genetic divergence for grain yield and its component characters to provide a basis for selection of parents in hybridization programme in maize.

Materials and methods

Experimental material

The present investigation was carried out during *kharif* 2016 at Maize Research Station, Sardarkrushinagar Dantiwada Agricultural University, Bhiloda District Aravalli using 46 maize inbred lines under rainfed condition. Inbreds were sown with onset of monsoon and no irrigation was applied. Inbred lines were evaluated in Randomized Block Design (RBD) with three replications with a row length of 4m and spacing of 60 cm between the rows and 20 cm between plants. Recommended management practices suggested for rainfed ecology were followed during crop growth period to raise a healthy crop. The data were recorded for four phenological traits viz., days to 50% tasseling, days to 50% silking, anthesis silk interval and days to 75% husk maturity, three plant architecture related traits i.e., plant height (cm), ear height (cm) and leaf area (cm^2), six yield related traits viz., cob diameter, cob length (cm), 100-seed weight (g), number of kernels per row, cob weight per plant (g) and grain yield per plant (g) and three quality traits i.e., protein content (%), starch (%) and zinc content (ppm).

Statistical analysis

Data recorded on mean of five randomly selected plants from each replication was used for statistical analysis. Selfed cobs were utilsed for protein content, starch and zinc content analysis. Standard statistical procedure was used for analysis of variance (Panse and Sukhatme, 1995). The cluster analysis was performed using the R programming (Ward method) with Euclidean distance coefficient to evaluate dissimilarity among all the inbreds. The principal component analysis method explained by Harman (1976) was followed in the extraction of the components to know the importance of different traits in explaining multivariate polymorphism using IRRI software STAR.

Results

Principle component

The analysis of variance for 46 inbred lines of maize for sixteen quantitative traits showed significant differences between the inbred lines for the characters studied indicating a presence of considerable amount of genetic variability in the studied material. (Data not showed). Similar findings were reported by Kamara *et al.* (2020). In principal component (PC) analysis, the number of variables was reduced to linear functions called canonical vectors which accounted for most of the variation produced by the characters under study. The eigen values, per cent variance, per cent cumulative variance and factor loading of different characters studied are presented in Table 1. In this experiment, first six principal components based on 17 quantitative traits showed eigen values greater than 1. The contribution of these six PCs was 76.25 per cent in the overall variability among the genotypes. The contribution of PC1 was found to be 25.99 per cent in

Table 1. Eigen values, proportion of the total variance represented by first six principal components and component loading of different characters in maize (*Zea mays* L.)

Particulars	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6
Eigen value (root)	4.41	3.37	1.59	1.36	1.19	1.02
% Var. Exp.	25.99	19.85	9.36	8.03	7.01	6.01
Cumulative proportion	25.99	45.84	55.20	63.23	70.24	76.25
Days to 50% tasseling	0.13	-0.48	0.09	-0.04	0.00	-0.02
Days to 50% silking	0.17	-0.48	0.04	-0.03	-0.06	0.01
Anthesis silk interval	0.19	-0.42	0.06	-0.0	-0.14	0.10
Days to maturity	0.06	-0.37	-0.04	0.20	0.33	0.05
Plant height	-0.34	-0.09	0.27	-0.26	0.20	0.09
Ear height	-0.33	0.08	0.32	-0.27	0.18	0.14
Leaf area	-0.27	-0.02	-0.16	0.26	0.23	0.03
Grain yield per plant	-0.37	-0.15	-.018	-0.04	-0.15	0.03
Grain weight per plant	-0.33	-0.10	-0.24	0.22	0.09	0.24
Cob diameter	-0.38	-0.08	-0.02	-0.04	-0.19	-0.08
Cob length	-0.31	0.09	0.11	-0.05	-0.28	-0.31
Number of kernels per row	-0.25	-0.29	-0.12	-0.12	-0.32	0.12
100-seed weight length	0.11	-0.11	-0.15	0.53	-0.20	-0.44
Protein content (%)	-0.01	-0.0	-0.35	-0.35	0.40	-0.28
Starch Content (%)	0.00	-0.14	-0.42	-0.27	0.22	-0.40
Zinc content (ppm)	-0.15	-0.03	0.35	0.39	0.46	-0.12

PC = Principal component

the total divergence of the studied population, in which the major contributing traits were ear height, plant height grain weight per plant, cob diameter and cob length. The second principal component (PC2) accounted for about 19.85 per cent of the total variation and was strongly associated with days to 50% silking and days to 50% tasseling, anthesis silk interval and days to 75% husk maturity. The third principal component (PC3) explained 9.36 per cent of variation and was associated mainly with plant height, ear height, and cob weight. The fourth principal component (PC4) explained 8.03 per cent variation and was contributed by 100 grain weight and Zinc content. Fifth and sixth principle components explained 7.01 and 6.01 per cent phenotypic variation and mainly contributed by protein content, number of kernels per row zinc content and 100 kernel weight respectively. Cluster analysis based on PCA scores were compared with the results of the principal component analysis on a visual aid in desecrating clusters in the two dimensional scattered diagram and the genotypes falling in same cluster were present closer to each other in the scattered diagram.

Two dimensional scatter diagram has been shown in Figure 1, and the genotypes numbered 01 and 41, GYL-1 and BLD 16 scattered away from other genotypes. These results are in accordance with those of Jinnu *et al.* (2009);

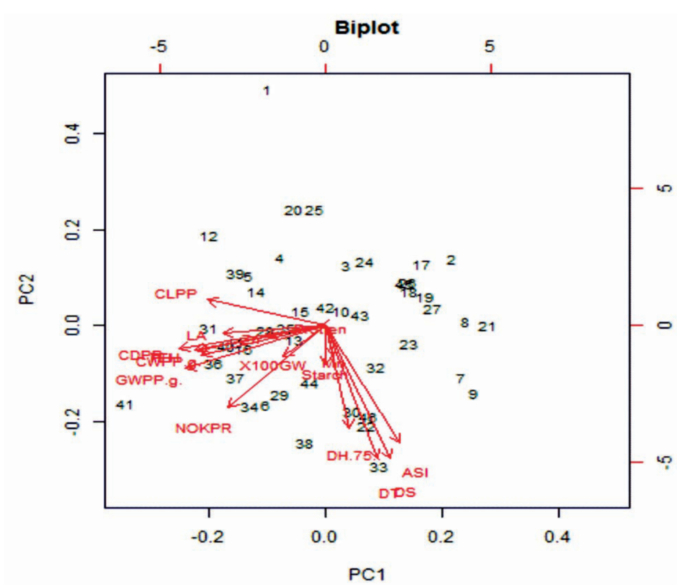

Figure 1. Biplot of the studied 16 variables of 46 maize inbreds.

Table 2. Composition of maize inbreds into 6 different clusters

Cluster No.	Genotypes included
I	BLD- 297, BLD-173, WNC-32177
II	GYL- 1, GYL-7, WNC-32160, VL-109178, WNC-18242, CML-15, BLD-276, BLD-46, BLD-51, BLD-208, BLD-131, BLD-223, BLD-94
III	BLD-100, HY10RN-10235-235, HY10RN-10235-269, WNC-32862, I-07-5-8, VL1032-1
IV	WNC-18354, IC-070, WNC-32867, BLD-232, BLD-16
V	WNC-32863, BLD-30, WNC-18005, VL109180, Z489-157, BLD-42, BLD- 265, BLD-188
VI	WNC-31734, BLD-74, BLD-76, WNC-31857, WNC-32255, BLD-2, GYL-5, WNC-18115, BLD-203, BLD-128, WNC-31708

Sandeep *et al.* (2015); Avinash and Mishra (2016); and Magudeeswari (2019) in maize crop.

Clustering of the genotypes

The six clusters account for 95 per cent of the variations among all the maize inbreds, in other words, 6 clusters were necessary to explain 95 per cent of the variations among the 46 genotypes. Cluster analysis was approved as a suitable method for data classifying as suggested by (Mohammadi and Prasanna, 2003). Based on the cluster analysis (Table 2 and Figure 2) 46 inbreds can be divided into 6 clusters based on the studied various agronomic and quality traits. Cluster number 4 was the highest in grain weight per plant. (113.91g), cob diameter per plant (13.25), cob length per plant (14.94 cm) and number of kernels per row (28.40), suggesting that this cluster demonstrated the relationship between grain yield and cob diameter per plant, cob length per plant and number of

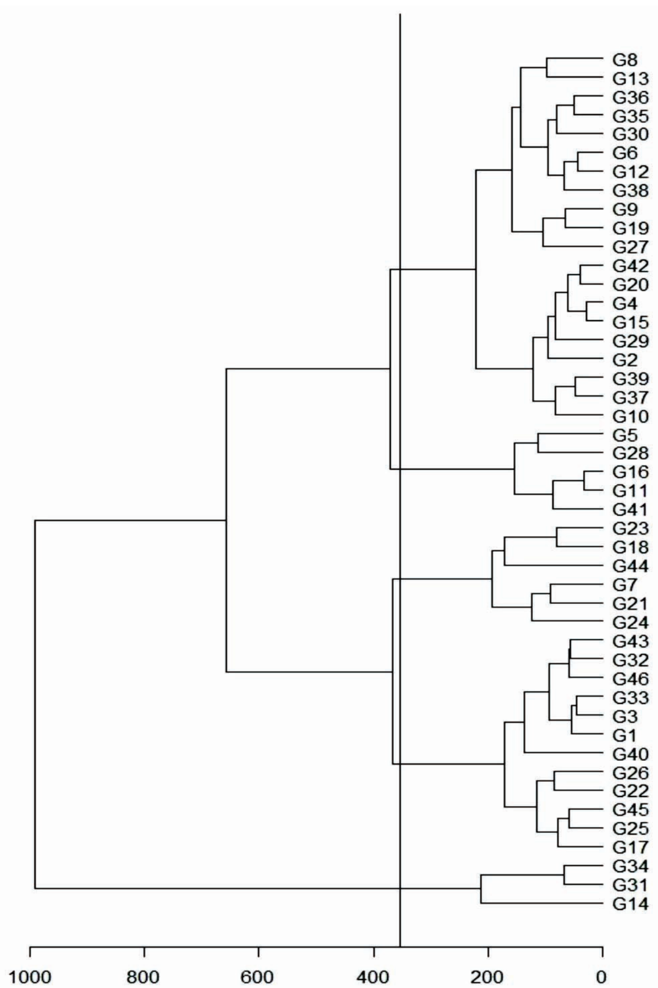

Figure 2. Dendrogram showing cluster analysis (ward method) of 46 maize inbred lines

Table 3. Contribution of sixteen characters under study to total divergence

Character	No. of time ranked first	% contribution towards divergence
Days to 50% tasseling	0	0
Days to 50% silking	0	0
Plant height (cm)	1	0.105
Anthesis silking interval	16	1.69
Ear height (cm)	0	0
Leaf area (cm^2)	0	0
Grain weight per plant (g)	94	9.93
Cob diameter per plant (mm)	0	0
Cob length per plant (Cm)	0	0
Number of kernel per row	16	1.69
Number of kernel row per cob	72	8.12
Days to 75% husking	7	0.73
100 grain weight (g)	27	2.85
Starch content (%)	32	3.38
Protein content (%)	233	24.63
Zn content (ppm)	144	15.22

Table 4. Mean values of different traits for maize inbreds

Code	Genotype	Days to 50% tasseling	Days to 50% silking	Days to 75% husking	Grain weight per plant (g)	Protein content (%)	Starch content (%)	Zn content (ppm)
G1	GYL-1	48	50	67.19	88.96	11.98	64.19	22.00
G2	GYL-5	50	55	72.57	50.11	11.08	63.85	25.33
G3	GYL-7	51	55	72.59	50.31	14.91	64.76	20.67
G4	BLD-2	49	54	70.72	86.87	10.89	63.23	27.33
G5	IC-070	50	54	71.67	60.73	1.44	60.96	32.00
G6	BLD-30	52	56	75.39	124.17	14.57	65.20	28.00
G7	I-07-5-8	53	58	78.35	55.88	8.15	63.27	29.33
G8	WNC-32160	52	56	75.39	46.36	3.13	63.33	30.00
G9	WNC-31734	53	58	79.30	33.68	12.41	64.29	22.00
G10	WNC-32255	51	55	73.52	78.96	12.82	65.33	24.67
G11	WNC-32867	51	55	76.61	142.40	7.99	65.06	39.33
G12	WNC-32863	48	52	74.46	139.84	10.91	63.16	39.33
G13	WNC-18005	51	55	79.38	70.79	10.57	63.82	32.00
G14	WNC-32177	50	53	78.32	104.33	9.27	63.72	37.33
G15	WNC-18115	51	55	77.36	77.29	6.72	63.57	32.67
G16	WNC-18354	51	55	75.35	136.21	14.65	65.18	26.67
G17	WNC-18242	50	54	74.39	23.63	10.20	64.56	30.00
G18	WNC-32862	51	54	75.39	78.21	11.97	65.06	24.67
G19	WNC-31857	51	56	75.39	56.56	8.95	61.94	43.00
G20	WNC-31708	49	52	73.47	102.67	12.74	62.66	29.00
G21	HY10RN-10235-235	52	57	75.39	63.12	8.48	63.34	28.00
G22	CML-15	53	59	78.42	103.88	15.34	64.48	20.67
G23	HY10RN-10235-269	52	57	76.33	59.91	8.47	63.55	30.00
G24	VL1032-1	50	53	77.36	72.43	11.04	62.67	26.00
G25	VL109178	50	52	75.35	65.07	7.37	63.47	58.67
G26	VL109180	50	54	78.37	53.73	13.67	64.62	15.00
G27	Z489-157	51	55	78.35	58.87	14.81	63.77	32.00
G28	BLD-232	51	55	76.44	101.40	5.33	62.88	29.33
G29	BLD-203	52	57	76.46	129.15	15.32	63.21	22.00
G30	BLD-188	52	56	79.35	122.15	0.94	66.16	26.00
G31	BLD-297	50	53	78.32	101.68	15.57	65.41	34.00
G32	BLD-276	52	56	77.39	61.40	14.26	63.19	28.00
G33	BLD-46	53	60	80.39	90.63	10.62	63.93	24.67
G34	BLD-173	52	57	78.35	115.00	10.31	64.60	43.33
G35	BLD-265	51	54	75.39	99.96	11.58	64.10	39.33
G36	BLD-51	51	55	78.32	135.12	6.74	62.40	36.67
G37	BLD-74	52	56	75.39	133.09	10.47	63.63	29.33
G38	BLD-42	53	58	78.32	120.87	10.86	65.29	41.33
G39	BLD-76	50	53	75.39	105.43	13.22	63.33	32.33
G40	BLD-208	51	55	75.39	130.07	3.73	64.12	22.67

Table 4 contd...

Code	Genotype	Days to 50% tasseling	Days to 50% silking	Days to 75% husking	Grain weight per plant (g)	Protein content (%)	Starch content (%)	Zn content (ppm)
G41	BLD-16	52	56	78.42	128.79	12.20	63.77	53.40
G42	BLD-128	50	54	79.35	105.59	10.73	64.14	18.67
G43	BLD-131	51	54	75.39	78.60	7.73	64.26	21.33
G44	BLD-100	52	56	75.42	132.11	8.09	63.68	16.67
G45	BLD-223	50	54	80.36	56.88	8.87	63.87	21.67
G46	BLD-94	53	58	79.38	56.87	12.98	63.75	52.00
	$\overline{X}$	51.10	55.29	76.30	88.91	10.31	63.89	30.40
	S.Em.±	0.65	0.87	1.05	23.18	0.34	0.21	1.17
	C.D at 5%	1.82	2.44	2.96	6.5	0.96	0.59	3.28
	C.V.%	2.19	2.72	2.39	9.03	5.76	0.57	6.65

kernels per row. On the other hand, the first cluster was highest in leaf area (3095.53), protein content (11.72 per cent), starch (64.57 per cent) and zinc content (38.22 ppm). The second cluster and third cluster were the lowest in grain weight per plant, number of kernels per row (71.76 g) and leaf area (1499.82) and cob weight per plant (128.53 g), cob length per plant (12.07 cm) and protein, starch and zinc (9.37 per cent, 63.59 per cent and 25.78 ppm), respectively. Every cluster can be represented by any variety belonging to that cluster; this will be useful in reducing the number of genotypes being tested in the next evaluation. The current findings of cluster analysis are in agreement with those obtained by Bakry *et al.* (2014), Ibrahim *et al.* (2016) and Nagar *et al.* (2020) who mentioned that agronomic parameters were useful in clustering flax, wheat and maize genotypes respectively using conventional cluster analysis.

Contribution of various characters towards genetic divergence

The analysis for estimating the contribution of various characters towards the expression of genetic divergence indicated that characters protein content (24.63 per cent), zinc content (15.22 per cent), grain weight per plant (9.93 per cent), number of kernel row per cob (8.12 per cent), starch content (3.38 per cent), 100 grain weight (2.85 per cent) contributed very much towards genetic divergence in the present material (Table 3). Meena *et al.* (2014) Maruthi *et al.* (2015) and Rekha *et al.* (2016) reported the similar findings for major contributors to genetic diversity.

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Maize Journal (October 2020) 9(2): 94-98

RESEARCH PAPER

Evaluation of integrated pest management technologies for the management of fall Armyworm *Spodoptera frugiperda* (J.E. Smith) on maize in Tamil Nadu

B. Geetha · S. R. Venkatachalam

Abstract: Fall armyworm, (FAW) *Spodoptera frugiperda* (J.E. Smith), an invasive lepidopteran pest, caused severe damage in maize crop in an area of 35,000 ha, in Salem and Namakkal districts of Tamil Nadu during September to November, 2018. The field experiment was conducted to evaluate the effectiveness of IPM technology against fall armyworm in maize. Integrated pest management (IPM) was found significantly superior which caused the maximum reduction of FAW larval population. In terms of number of larvae in plant (0.03-0.10), leaf damage (22.33 – 56.67 per cent), per cent damage in tassel (10 per cent) and ears (3.33 – 42.67 per cent), An increased average yield of 8920 kg/ha was obtained with higher benefit ratio of 4.05 in IPM fields when compared to poor yield of 4750 kg/ha and low benefit ratio of 1.29 in non-IPM fields. Implementation of IPM technology with the adoption rate of 90 to 95 per cent in these districts resulted reduction in damage level *viz*., leaf damage 10-18 per cent, whorl damage 6-15 per cent, tassel damage, 5-8 per cent and cob damage of 2 per cent. Natural enemies in IPM fields was observed maximum from 0.37 to 1.33 number/plant where as in non –IPM fields, natural enemies population was very low. IPM technology proved sustainable in FAW management with higher yield with healthy ears and better grain filling.

Keywords: Maize · Fall armyworm · IPM technology · Damage of leaf whorl · Tassel and cob stage

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Received: 08 November 2020/ Accepted: 28 November 2020

Introduction

Maize (*Zea mays* L.) is one of the most widely grown cereal crop in India, grown for various purposes including feed, food, fodder and as a basic raw material for industrial products. The productivity of maize is challenged by various biotic and abiotic factors. Among biotic factors, over 130 insect pests cause varying degree of damage from seedling to maturity stage of maize crop (Chatterjee *et al.*, 1969). Maize plants are severely attacked by different species of lepidopteran pests. Another notorious pest fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) was observed for first time in India in Karnataka state (Ganiger *et al.*, 2018). Fall armyworm is a polyphagous pest (Todd and Podde, 1988), native to tropical and subtropical America that attacks over 80 different crop species, but with a preference for graminaceous crops and particular in maize crop (Sparks, 1979). It attacks young maize plants and causes damage of leaves, tassel and cob which leads to drastic yield losses (Simeada, 1985). FAW was considered as the major insect pest for the maize causing upto 34 per cent reduction in the grain yield (Lima *et al.,* 2010). Its attack was severe in South Indian state of Karnataka followed by Tamil Nadu and Andhra Pradesh states that are major regions for hybrid maize (Sharanabasappa *et al.,* 2018). The occurrence of FAW spreads from maize to bajra and sorghum to other millet crops in Ananthapuramu district, Andhra Pradesh because it attacks mainly maize, but it has the ability to survive on many graminaceous plants like Sorghum, Bajra, finger millet etc., (Venkateswarlu *et al.*, 2018). In Tamil Nadu, FAW caused severe damage in maize crop in Salem and Namakkal districts during

September to November, 2018 in maize hybrids viz., Cargill, Pioneer, NK6240, CP818, CP808, Sivani, KSMH 1980, Kaveri 25. In Salem district, among the maize area of 35,000 ha, FAW caused 38 to 50 per cent damage in 9 maize growing blocks viz., Thailaivasal, Attur, Gangavalli, Pethanaikanpalayam, Valapadi, Ayothiyapattinam, Kolathur, Edapadi and Kadayampatti. In Namakkal district, among 15 blocks, 28 to 52 per cent damage was recorded in 8 maize growing blocks viz., Namakkal, Paramathivelur, puduchattiram, Rasipuram, Namagiripettai, Vennanthur, Kabilarmalai and Mallasamuthiram. IPM methods based on agronomic management represent an alternate with lower risk for health and the environment (Thierfelder *et al*., 2018). Hence, a study was conducted for evaluating the damage of FAW in maize and the efficacy of IPM technologies on management in Tamil Nadu.

Materials and methods

Field experiments were conducted in Salem and Namakkal districts of Tamil Nadu to assess the damage of FAW in maize and the efficacy of IPM technologies on its management during *kharif* 2019. The experiment consists of three treatments and each treatment was laid out in one acre area in farmers field. Treatments were laid out in Randomized Block Design (RBD) with seven replications. The treatments were

T_1 – IPM technology

- Summer ploughing
- Application of neem cake @ 250 kg/ha
- Adopting rogue spacing
- Sowing of insecticides treated seeds (thiamethoxam 30 FS @ 10 g/kg) as such sold in the market
- Sowing of inter crop with Cowpea and border crop with redgram
- Hand picking and destruction of egg masses and larvae
- Installation of pheromone traps for mass trapping @ 50 numbers/ ha
- Application of the insecticides as,
- First spray Azadirachtin 1% (10000 ppm) @ 2ml / lit. during early whorl stage (15-20 DAS)
- Second spray Spinetoram 12 SC 0.5 ml/ lit. during late whorl stage (40-45 DAS)

T_2 – Farmers practice: Application of Carbofuran 3G @ 33 kg/ha mixed with 50 kg sand

T_3–Untreated control: No management practices

Table 1. Evaluation of Fall armyworm management practices in leaf and whorl stage of maize

Treatments	Location I (Namakkal)						Location II (Salem)					
	15 DAS		30 DAS		45 DAS		15 DAS		30 DAS		45 DAS	
	Damage (%)	Larvae Population (%)	Damage (%)	Larvae Population (%)	Damage (%)	Larvae Population (%)	Damage (%)	Larvae Population (%)	Damage (%)	Larvae Population (%)	Damage (%)	Larvae Population (%)
IPMTechnology	6.67	0.03	10.00	0.08	3.33	0.10	6.67	0.10	10.00	0.20	6.67	0.10
Farmers practice	22.33	0.23	56.67	0.58	76.67	0.68	28.33	0.53	36.67	0.78	26.67	0.68
Untreated	37.33	0.56	76.33	0.98	80.33	0.93	41.33	0.86	56.67	1.07	40.33	0.93
S Ed	0.54	0.03	0.30	0.03	0.37	0.04	0.60	0.07	0.50	0.05	0.42	0.03
CD (0.5)	1.18	0.08	0.66	0.07	0.82	0.08	1.96	0.14	0.86	0.09	1.12	0.07

Data are the mean of seven replications and each replication data mean of data obtained from 10 plants

Data harvest time cob damage excluding bird damage

In this study, IPM technologies were followed from the land preparation till harvest with adoption of general agronomic packages. Pheromone traps were laid at 20 DAS. A total of two insecticides sprays viz., Azadirachtin 1% (10000 ppm) @ 2ml / lit and Spinetoram 12 SC 0.5 ml/ lit. were given at early and late whorl stages. Observations on the incidence of larval population, damage of leaf, whorl stage and tassel and ear stage, natural enemies population and yield data were recorded in all the treatments and compared. Observations on larval population and damage were recorded at 15, 30, 45, 60 and 75 days after sowing. Data were subjected to statistical analysis by using ANOVA (Analysis of Variance software version 7.01). The benefit cost ratio was also calculated by dividing the net profit over the control by the total cost.

Results and discussion

Fall armyworm damage and larval population in maize in experimental fields are given in Tables 1 to 2. In IPM technology, the leaf whorl damage was minimum ranged from 3.33 to 10.00 per cent in Namakkal district however in Salem the leaf whorl damage was ranging from 6.67 to 10.00 per cent when compared to non IPM fields. Fall armyworm larval population was much lower in IPM technologies adopted fields which ranged from 0.03 to 0.10 numbers/ plant in the fields of Namakkal district and 0.10 to 0.20 number/ plant in Salem district at 15 DAS to 45 DAS when compared to the farmers practice. (Table 1). Implementation of IPM technology in the study districts resulted in reduction of both tassel and ear damage with the per cent of 3.33 to 10.00 at 60 and 75 DAS whereas in farmers practice the tassel and ear damage was high ranging from 38.67 to 43.33 per cent and untreated check (53.67 - 60.00%). Similarly, Kumela *et al*. (2018) also reported the higher incidence of FAW in their study with leaf damage of 26.4 – 41.5 per cent in Chipinge and 36.8–54.9 per cent in Makoni over the past two years in farmers holdings. The damage in maize varied with stage of the crop from early whorl to ear formation stage. Gross *et al*. (1982) also reported that FAW attack and larvae are most often found defoliating in mid-vegetative growth stages and FAW damage varied with maize growth stages in their susceptibility to leaves within the whorl. In the present study, the level of FAW incidence was comparatively low in IPM technology implemented fields intercropped with cowpea which attracted more of natural enemies. Altieri *et al.* (1978) reported the reduced FAW incidence as whorl feeder in maize by 23 per cent when maize was intercropped with beans in Colombia. The data on grain yield also revealed that IPM technology has recorded the highest grain yield of 8920 kg/ha with higher benefit cost ratio of 4.05 while the untreated check recorded the lowest grain yield of 2015 kg/ ha. Whereas in farmer practice the average yield of 4750 kg/ha with the low benefit cost ratio of 2.01 was recorded (Table 2). Natural enemies population was high in IPM technology adopted fields. Among the natural enemies, the predators viz. grubs and adults of Coccinellids, Chrysopids viz., *Chrysoperla zastrowi and Mallada sp* and spiders population ranged from 0.37 to 1.67 number/ plant were observed in IPM fields when compared to farmers practice and untreated check. Three species of parasitoids namely, *Cotesia icipe*, *Palexorista zonata* and *Charops ater* were recovered from FAW larvae in Ethiopia which responsible for population reduction of FAW to 20 per cent (Birhanu, 2018). In farmers practice fields, the population

Table 2. Evaluation of Fall armyworm management practices in tassel and ear formation stage in maize

Treatments	Location I (Namakkal)					Location II (Salem)				
	Tassel damage (%) at 60 DAS	Cob damage (%) at 75 DAS	Grain yield (kg/ha)	Gross return (Rs.)	BCR	Tassel damage (%) at 60 DAS	Cob damage (%) at 75 DAS	Grain Yield (kg/ha)	Gross return (Rs.)	BCR
IPM Technology	10.00	3.33	8570	1,54,260	1:3.92	10.00	3.33	8920	1,60,560	1:4.05
Farmers practice	43.33	42.67	4280	77,040	1: 1.85	43.33	38.67	4750	85,500	1: 2.01
Untreated	53.00	58.33	1895	34,110	1:1.20	60.00	53.67	2015	36,270	1:1.29
S Ed	0.30	0.43	-	-	-	0.36	0.54	-	-	-
CD (0.5)	0.67	0.95	-	-	-	0.69	1.12	-	-	-

Data are the mean of seven replications and each replication data mean of data obtained from 10 plants
Sale price of Maize grain: Rs 18 / kg

Table 3. Comparative population of natural enemies in various management practices for fall armyworm in maize

Treatments	Location I (Namakkal)					Location II (Salem)				
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
	Population / plant					Population / plant				
IPM Technology	0.37	0.53	1.07	1.27	0.66	0.57	1.33	1.07	1.67	0.96
Farmers practice	0.27	0.13	0.13	0.07	0.09	0.17	0.27	0.33	0.17	0.23
Untreated	0.13	0.23	0.43	0.43	0.23	0.29	1.17	0.73	0.40	0.56
S Ed	0.02	0.01	0.01	0.02	0.02	0.03	0.02	0.04	0.03	0.01
CD (0.5)	0.05	0.03	0.02	0.06	0.05	0.07	0.06	0.09	0.07	0.04

Data are the mean of seven replications and each replication data mean obtained from 10 plants

of natural enemies found drastically reduced from the early stage of crop growth to harvest due to repeated application of insecticides. In untreated check where insecticides not sprayed recorded moderate population of natural enemies ranged from 0.13 to 1.17 in both the districts (Table 3).

Conclusion

The studies showed that the IPM technologies adopted in this experimental trials was more effective in management of FAW in maize when compared to farmer practice and untreated check in both the districts of Tamil Nadu. Natural enemies population was also high in IPM technology treatment which showed safer to natural enemies and environment. Significant reduction of FAW damage in IPM technology was found with higher benefit cost ratio. Population buildup of FAW was also slow in IPM technology treatment which proved IPM technologies as a sustainable FAW management practices with higher yield with healthy ears and better grain filling. So it is suggested that IPM technology can be used to manage the FAW in maize.

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Maize Journal (October 2020) 9(2): 99-107

RESEARCH PAPER

Studies on associated effects of trichome length and density on infestation of maize spotted stemborer, *Chilo partellus* (Swinhoe)

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Abstract: With the aim of finding the association between the density and lengths of trichomes and its effects on infestation and survival of maize spotted stemborer, *Chilo partellus*, 25 maize genotypes *viz.*, Shaktiman-1, Shaktiman-2, Shaktiman-3, Shaktiman-4, Shaktiman-5, RHM-1, RHM-2, RHM-3, P-3535, P-3533, P-3550, P-3555, Dekalb-9188, Dekalb-9170, composite namely Devaki, Laxmi, Suwan, Deep Jwala and promising genotypes namely New Cross 76×11, New Cross 72×70, New Cross 73×11, New Cross 73×74, New Cross 52×65, New Cross 53×52 and New Cross 50×58 were studied during the year 2018 and 2019. The data of trichome density and lengths have been taken at two different crop stages while the data of different infestations has been taken after 20 days of infestation and at just before the tasseling. The results clearly indicated that genotypes having higher density of trichomes showed the smaller lengths of trichomes while their correlation with different infestation parameters revealed a positive correlation between trichome density and infestation parameters while negative in case of trichome length and infestation parameters. The effect of density on trichome length was recorded to be negatively correlated while the growing age of plants showed negative correlation with density of trichomes. In case of tested genotypes, genotypes having greater density of trichomes namely, New Cross (72×70); Suwan; Deep Jwala; New Cross (53×52); DeKalb 9170; RHM-3; New Cross (52×65); New Cross (50×58); Shaktiman-4; P-3555; New Cross (76×11); New Cross (73×74); P-3533; Shaktiman-2 found to be lesser infested with maize spotted stem borer.

Keywords: *Chilo partellus* · Host plant resistance · Infestation · Maize · Trichome density · Trichome length

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Received: 31 August 2020/ Accepted: 15 November 2020

Introduction

Maize is grown around the world for food, feed, and fodder (Kakar *et al*., 2003). It is important for human and animal nutrition and serve as staple food in a number of developed and developing countries. It is also used for the production of cooking oil, food additives such as sweeteners and thickeners, alcohol-based drinks, etc. It serve as industrial raw material for the production biofuel, starch, gelatin, lactic acid etc. Maize in India is used as a source of poultry feed (43 per cent), food purpose (23 per cent), cattle feed (17 per cent), starch industry (14 per cent), brewery (2 per cent) and seed (1 per cent). Maize consumption in India has grown up to 19 million tones (Anonymous, 2019).

There are many causes behind the low productivity of Maize in India like very less mechanization, use of indigenous seeds and old practices of crop production and biotic and abiotic stresses such as insect pests, diseases and weeds (Ali *et al.*, 2012). In all the above-mentioned threats, insects-pests alone can cause up to 80 per cent damage to the crop during both the seasons (Rahman, 1994). There are several pests reported to damage maize crop on different crop stages, in which spotted stemborer

(*Chilo partellus*), pink stemborer (*Sesamia inferens*) and fall armyworm (*Spodoptera frugiperda*) are the major ones. Corn earworm (*H. armigera*), cutworm (*Agrotis* sp.) and corn aphid (*Rhopalosiphum maidis*) are sporadic pests, which sometimes causes economic damage (Anonymous, 2020).

Spotted stemborer is the major pests of *kharif* maize, most damaging in high temperature and high relative humidity, found to be infesting the crop from mid July to end of September and larvae undergo hibernation in stem at the end of the *kharif* season. Typical damage symptoms include pinholes, shot holes and window on leaves, dead-hearts and exit-holes and dwarfing while internal symptoms include stem tunneling (Kumar, 1994). A typical maize plant has many traits to deter infestation of insects-pests such as physical, morphological and biochemical characters.

The most chosen method to protect crops from the insect-pests is the application of synthetic pesticides, which cause adverse effects to the environment. Whereas, host plant resistance is an important tool of crop protection which do not cause any adverse effect on nature. It is the innate ability of the plant to defend pests. Maize plants are well known for having many traits imparting resistance against several pests like long stem, more nodes and smaller internodes, *etc.* trichomes or body hairs of maize found throughout the surface of maize plants excluding roots and lower surface of leaves. These hairs have their own significance in management of insect-pests. Therefore, the present study was designed with the aim of finding the association between trichome density and trichome length with spotted stemborer, infestation.

Materials and methods

To conduct the present experiment, 25 genotypes (local population, hybrid, composite and promising genotypes) were obtained from the Department of Plant Breeding and Genetics, Tirhut College of Agriculture Dholi, Muzaffarpur (Table 1).

In the selected genotypes, Lakshmi was used as resistant check to calibrate the degree of susceptibility of different genotypes against the test insect *i.e.*, spotted stemborer.

Rearing of maize spotted stemborer, Chilo partellus

Spotted stemborer larvae were collected from Borlaug Institute for South-Asia for Wheat & Maize and Research Farm, Tirhut College of Agriculture (TCA) Dholi, Muzaffarpur. Collected larvae were reared in stalks of CML-186 due to its high-level susceptibility to spotted stemborer. For which, a susceptibility test was conducted with CML-186, CML-165, CML-169, CML-373 and HKI-586 in three replications. CML-186 found to be the best performer on the basis of total infestation, larval survival and pupal weight. All the infested stalks were placed inside the cage under room temperature (25°C ± 2°C with proper supply of moisture to maintain required relative humidity. The stalks were changed at every 2-3 days of intervals as described in literature by Taneja and Nawanze (1990); Songa *et al*. (2001); Kega *et al*. (2011); Owens (1984). Pupae were isolated to moth emerging cages. The pupal periods vary from 4-7 days, which is more for females in compare to male moths. Moths were placed in another moth cage lined with a double layered wax paper for mating and egg laying. Egg patches were isolated by cutting whole patch including the wax paper. Egg patches were placed inside the whorls of 20-25 days old plants and reared till next generation with periodic changes of plants/stalk. Next generation was reared on semi-synthetic diet prepared as suggested by Sarup *et al*. (1987).

Sowing of crop

A total number of 25 maize genotypes (Table 1) were sown during *kharif* (2018 and 2019), in Randomized Block Design with total number of 4 replications, in mid-July in research farm of RPCAU Pusa. Data on the following has been recorded at specified times during the 2018 and 2019:

Trichome density

For the assessment of trichome number, five plants were selected from each replication of each treatment and 3rd and 4th leaves were taken for assessment. Patches of 1 cm^2 were cut from three paces of a leaf *viz*., apical leave, proximal end and middle of the leaf with the help of surgical blade. The total number of trichomes were counted with the help of 10× magnification. The data was taken 40 days after sowing and just before the tasseling stage.

Trichome length

Trichomes were extracted of the 1 cm^2 patches used for trichome density measurement. For extraction, leaves

Table 1. List of genotypes

S.No.	Genotypes
1.	Shaktiman-1
2.	Shaktiman-2
3.	Shaktiman-3
4.	Shaktiman-4
5.	Shaktiman-5
6.	Devaki
7.	Lakshmi (Check, Resistant)
8.	Suwan
9.	RHM-1
10.	RHM-2
11.	RHM-3
12.	Deep Jwala
13.	P-3535
14.	P-3533
15.	P-3550
16.	P-3555
17.	DeKalb-9188
18.	DeKalb-9170
19.	New Cross (76×11) Pool 17 QPM-B7×CML-165
20.	New Cross (72×70) CML-163-7-2×CML-196
21.	New Cross (73×11) Dholi pop -65×CML-165
22.	New Cross (73×74) Dholi pop -65×CML-373
23.	New Cross (52×65) HKI-1105×2006-6-CML-471
24.	New Cross (53×52) Dholi pop-65×HKI-1105
25.	New Cross (50×58) HKI-586×Pop Dholi

chlorophyll was erased with the help of organic solvents like Di Methyl Sulpho-oxide and Ethanol by heating leaves in organic solvent for 12 hours at 60^{o}C in BOD. Trichomes were extracted by using fine forceps, needles and surgical blades.

Number of larvae and pupae

To assess the ability of different genotypes to support larval population, leaf injury score of 5 number of plants/ replication were recorded first. The plants were cut after the tasseling, larvae and pupae were recovered and expressed as number of larvae and pupae per plant.

Number of infested plants

The data has been recorded after 20 days of artificial infestation. Number of healthy and infested plants were counted WHEN? Extent of pest infestation for each genotype was calculated by using the formula:

$$\text{Percent plant infestation} = \frac{\text{Number of infested plant}}{\text{Total number of plant}} \times 100$$

Statistical analysis

ANOVA?

Correlation analysis has been done between trichome density; trichome length and larval survival; pupal survival; per cent plant infestation.

Results

Trichome density

Mean trichome density per cm^2 for both the year during different crop stages are given in Table 2. At 40 days after sowing, trichome density per cm^2 ranged from 72.25/cm^2 to 94.75/cm^2 in different genotypes, where the maximum was recorded in RHM-3 with 94.75 trichomes/cm^2 followed by Deep Jwala with 94.00 and New Cross (73×74) with 93.00 trichomes/cm^2. Minimum leaf trichome density per cm^2 was recorded in Shaktiman-1 with 72.25 leaf trichome numbers per cm^2 followed by P-3550 with 74.50 and Shaktiman-5 with 75.00 leaf trichome numbers per cm^2. Leaf trichome density in Lakshmi (resistant check) was 91.00/cm^2 and it was found at par with the RHM-3, Deep Jwala, P-3555, New Cross (72×70) and New Cross (73×11).

Similarly, Trichome density just before tasseling different genotypes were ranged from 98.25/cm^2 to 116.50/ cm^2 in which the maximum leaf trichome density per cm^2 were recorded in New Cross (72×70) with 116.50 trichomes/cm^2 followed by Suwan with 116.00 and Deep Jwala with 115.50 trichomes/cm^2 and they found superior to the check. The minimum trichome density per cm^2 were recorded in Shaktiman-1 with 98.25 leaf trichome numbers per cm^2 followed by New Cross (73×11) with 99.25 and P-3550 with 99.75 leaf trichome density per cm^2. Leaf trichome numbers in Lakshmi (resistant check) were 106.00/cm^2 and that were at par with the Shaktiman-2 & 4, P-3533, P-3555, New Cross (76×11) and New Cross (73×11).

Table 2. trichome density and trichome lengths at different crop stages of various selected genotypes of maize during *kharif* 2018 and 2019

S.No.	Name of genotypes	Trichome density (2018 & 2019)		Trichome length (2018 & 2019)	
		40 days after sowing	40 days after sowing	40 days after sowing	40 days after sowing
1.	Shaktiman-1	72.25	98.25	11.05	11.88
2.	Shaktiman-2	79.00	106.25	10.86	11.73
3.	Shaktiman-3	83.50	103.00	9.21	10.20
4.	Shaktiman-4	84.25	108.25	11.00	11.41
5.	Shaktiman-5	75.00	104.75	7.46	8.20
6.	Devaki	77.75	102.00	7.95	7.63
7.	Lakshmi (Resistant, Check)	91.00	106.00	7.34	8.27
8.	Suwan	88.75	116.00	7.85	8.50
9.	RHM-1	86.25	103.75	9.29	10.07
10.	RHM-2	82.25	101.25	11.39	12.36
11.	RHM-3	94.75	113.75	6.30	7.34
12.	Deep Jwala	94.00	115.50	6.08	6.40
13.	P-3535	85.50	104.00	7.51	7.98
14.	P-3533	77.50	106.25	7.10	8.60
15.	P-3550	74.50	99.75	8.39	9.08
16.	P-3555	91.25	106.75	8.52	9.13
17.	DeKalb 9188	77.00	105.00	9.06	9.66
18.	DeKalb 9170	86.50	114.25	9.58	10.29
19.	New Cross (76×11)	85.50	106.50	11.27	12.16
20.	New Cross (72×70)	92.25	116.50	5.76	6.34
21.	New Cross (73×11)	91.00	99.25	6.35	6.82
22.	New Cross (73×74)	93.00	106.25	6.04	7.125
23.	New Cross (52×65)	88.50	112.50	6.17	7.34
24.	New Cross (53×52)	86.00	114.50	8.09	9.17
25.	New Cross (50×58)	88.25	108.50	8.19	8.72
	CD ≤5%	2.41	3.40	0.77	0.91
	SEm (±)	0.81	1.09	0.26	0.32

Trichome length

Mean trichome length for both the year during different crop stages are given in Table 2. At 40 days after sowing, leaf trichome lengths in different genotypes were ranged from 5.76 to 11.39 µm, where the maximum leaf trichomes length was recorded in RHM-2 with 11.39 µm followed by New Cross (76×11) with 11.27 and Shaktiman-1 with 11.05. Minimum trichome length was observed in New Cross (72×70) with 5.76 µm followed by New Cross (73×74) with 6.04 and Deep Jwala with 6.08 µm trichome lengths. Trichome length in resistant check Lakshmi was 7.34 µm and genotypes namely, New Cross (73×11); P-3533; Shaktiman-5; P-3535; Suwan; New Cross (50×58) were found at par with the resistance.

Leaf trichome lengths before-tasseling stage in different genotypes were ranged from 6.34 to 12.36 µm, where the maximum leaf trichomes was recorded in RHM-2 with 12.36 µm followed by New Cross (76×11) with 12.16 and Shaktiman-1 with 11.88 µm. Minimum trichome length was observed in New Cross (72×70) with 6.34 µm followed by Deep Jwala with 6.40 and New Cross (73×11) with 6.82 µm trichome lengths. Trichome length in resistant check Lakshmi was 8.27 µm and Shaktiman-5, Devaki, New Cross (53×52) and New Cross (50×58) were found at par with it.

Number of larvae and pupae

The number of larvae and pupae recovered from 25 genotypes after tasseling during *kharif* 2018 and 2019 are presented in Table 3.

During *kharif* 2018, at after tasseling stage, the larval survival in different genotypes ranged from 0.00 to 6.00 per plant in which the maximum survival was observed in RHM-2 with 6 larvae. Larval survival in the genotypes, P-3555, 4.00 and P-3550 with 3.50, Shaktiman-2&5 was found at par with resistance check Lakshmi (2.5). Minimum larval survival was recorded in Devaki; New Cross (73×74) with 0.00 larvae per plant followed by Shaktiman-3; New Cross (73×11) with 0.50 and Shaktiman-1; Shaktiman-4; RHM-1; New Cross (76×11); New Cross (72×70); New Cross (50×58) with 1.00 of larvae per plant. During *kharif* 2019, after tasseling stage, the larval survival in different genotypes ranged from 0.50 to 3.50 per plant in which the maximum larval survival was observed in RHM-2 with 3.50 followed by P-3550; Shaktiman-5,3.00 and P-3555; DeKalb 9170; DeKalb 9188; Shaktiman-2 with 2.50 larvae per plant. Minimum larval survival was recorded in Devaki; New Cross (73×74) with 0.00 larvae per plant followed by Shaktiman-3; New

Table 3. Larval survival and pupal survival of various selected genotypes of maize during *kharif* 2018 and 2019

S.No.	Name of genotypes	Larval survival (2018 & 2019)			Pupal survival (2018 & 2019)		
		Kharif 2018	*Kharif* 2019	Pool average of 2018 & 2019	*Kharif* 2018	*Kharif* 2019	Pool average of 2018 & 2019
1.	Shaktiman-1	1.00	1.50	1.25	1.50	0.50	1.00
2.	Shaktiman-2	2.50	2.50	2.50	1.00	1.00	1.00
3.	Shaktiman-3	0.50	0.50	0.50	0.00	0.50	0.25
4.	Shaktiman-4	1.00	1.00	1.00	2.50	1.50	2.00
5.	Shaktiman-5	2.50	3.00	2.75	0.50	0.50	0.50
6.	Devaki	0.00	0.50	0.25	2.50	1.50	2.00
7.	Lakshmi (Resistant, Check)	2.50	1.50	2.00	1.50	1.50	1.50
8.	Suwan	2.00	2.00	2.00	1.00	0.50	0.75
9.	RHM-1	1.00	0.50	0.75	1.50	1.50	1.50
10.	RHM-2	6.00	3.50	4.75	4.00	1.50	2.75
11.	RHM-3	1.50	1.50	1.50	1.00	1.00	1.00
12.	Deep Jwala	2.00	1.50	1.75	1.50	3.00	2.25
13.	P-3535	1.50	1.00	1.25	2.00	1.50	1.75
14.	P-3533	1.50	1.50	1.50	1.50	2.00	1.75
15.	P-3550	3.50	3.00	3.25	3.00	1.50	2.25
16.	P-3555	4.00	2.50	3.25	1.50	1.50	1.50
17.	DeKalb 9188	2.50	2.50	2.50	2.00	1.50	1.75
18.	DeKalb 9170	2.50	2.50	2.50	0.50	0.50	0.50
19.	New Cross (76×11)	1.00	0.50	0.75	2.50	2.50	2.50
20.	New Cross (72×70)	1.00	1.50	1.25	1.50	2.00	1.75
21.	New Cross (73×11)	0.50	0.50	0.50	0.50	0.50	0.50
22.	New Cross (73×74)	0.00	0.50	0.25	1.50	2.50	2.00
23.	New Cross (52×65)	1.50	2.00	1.75	0.50	2.00	1.25
24.	New Cross (53×52)	1.50	2.00	1.75	1.00	2.00	1.50
25.	New Cross (50×58)	1.00	1.00	1.00	1.00	2.00	1.50
	CD ≤ 5%	1.71	1.47	1.54	1.12	1.35	1.21
	SEm (±)	0.59	0.51	0.53	0.40	0.48	0.41

Cross (73×11); Shaktiman-3; New Cross (73×11); RHM-1; New Cross (76×11) with 0.50 and Shaktiman-4; New Cross (50×58); P-3535 with 1.00 of larvae per plant. The larval survival in resistant genotype, Lakshmi was 1.50 larvae per plant.

Mean intensity of larval survival of both the years after tasseling stage in different genotypes were ranged from 0.25 to 4.75 per plant in which the maximum larval survival was observed in RHM-2 with 4.75 and it was found superior to the resistance. The genotypes, P-3555; P-3550 with 3.25 and Shaktiman-5 with, 2.75 were found at par with resistance check. Minimum larval survival was recorded in Devaki; New Cross (73×74) with 0.25 larvae per plant followed by Shaktiman-3; New Cross (73×11) with 0.50 and RHM-1; New Cross (76×11) with 0.75 of larvae per plant.

During *kharif* 2018, after tasseling, the pupal survival in different genotypes were ranged from 0.00 to 4.00 per plant in which the maximum survival was observed in RHM-2 with 4.00 and P-3550, 3.00 and they were superior to the check (1.5). Following genotypes, New Cross (76×11); Devaki; Shaktiman-4with 2.50; Shaktiman-1, P-3535, Dekalb9188 and New Cross (76×11) were found at par with the resistance. Minimum pupal survival was recorded in Shaktiman-3 with 0.00 pupae per plant followed by Shaktiman-5; DeKalb 9170; New Cross (73×11); New Cross (52×65) with 0.50 and Shaktiman-2; Suwan; RHM-3; New Cross (53×52); New Cross (50×58) with 1.00 of pupae per plant. During *kharif* 2019, after tasseling, the pupal survival in different genotypes ranged from 0.50 to 3.00 per plant in which the maximum survival was observed in Deep Jwala with 3.00 followed by New Cross (76×11); New Cross (73×74) with 2.50 and New Cross (72×70); P-3533; New Cross (50×58); New Cross (53×52); New Cross (52×65) with 2.00 pupae per plant and they are at par with the resistance. Minimum pupal survival was recorded in Shaktiman-3; Shaktiman-5; DeKalb 9170; New Cross (73×11); Suwan; Shaktiman-1 with 0.50 pupae per plant followed by Shaktiman-2 and RHM-3 with 1.00 of pupae per plant.

Mean intensity of pupal survival of both the years after tasseling stage in different genotypes ranged from 0.25 to 2.75 per plant in which the maximum survival was observed in RHM-2 with 2.75 followed by New Cross (76×11) with 2.50 and P-3550; Deep Jwala with 2.25 pupal intensity and they were superior to the check (1.5). Following genotypes, RHM-1; P-3555; New Cross (53×52) and New Cross (50×58) were found at par with the resistance. Minimum pupal survival was recorded in Shaktiman-3 with 0.25 pupae per plant followed by Shaktiman-5; DeKalb 9170; New Cross (73×11) with 0.50 and Shaktiman-2; Suwan and Shaktiman-1 with 1.00 of pupae per plant.

Percent infestation

Percent infestation in 25 genotypes after 20 days of artificial infestation during *kharif* 2018 and 2019 is presented in Table 4.

During *kharif* 2018, after 20 days of infestation, per cent infestation in different genotypes ranged from 16.00 to 57.50 per cent in which the maximum infestation was observed in RHM-2 with 57.50 per cent followed by Shaktiman-5 with 53.50 per cent and P-3550 with 49.00 per cent. Minimum per cent infestation was recorded in New Cross (72×70) with 16.00 per cent followed by RHM-3 with 16.75 per cent and Deep Jwala with 17.00 per cent infestation. The percent infestation in resistant genotype, Lakshmi was 19.75 per cent which were at par with New Cross (73×11) and New Cross (50×58).

During *kharif* 2019, after 20 days of infestation, the total percent infestation in different genotypes ranged from 16.25 per cent to 48.00 per cent in which the maximum percent infestation was observed in RHM-2 with 48.00 per cent followed by P-3550 with 47.00 per cent and Shaktiman-5 with 43.50 per cent infestation. Minimum per cent infestation was recorded in New Cross (72×70) with 16.25 per cent followed by RHM-3; Lakshmi with 16.75 per cent and New Cross (52×65) with 18.00 per cent infestation. The percent infestation in resistant genotype, Lakshmi was 16.75 per cent, which were at par with the RHM-3, Deep Jwala and New Cross (52×65).

At after 20 days of infestation, the pooled mean percent infestation in different genotypes ranged from 16.12 per cent to 52.75 per cent in which the maximum per cent infestation was observed in RHM-2 with 52.75 per cent followed by Shaktiman-5 with 48.50 per cent and P-3550 with 48.00 per cent. Minimum percent infestation was recorded in New Cross (72×70) with 16.12 per cent followed by RHM-3 with 16.75 per cent and Deep Jwala with 17.87 per cent infestation. The percent infestation in resistant genotype, Lakshmi was 18.75 per cent which were at par with New Cross (73×11) and New Cross (50×58).

Table 4. Average plant infestation per cent in different genotypes of maize during *kharif* 2018 and 2019

S.No.	Name of genotypes	After 20 days of infestation 2018	After 20 days of infestation 2019	Pool average of 2018 and 2019
1.	Shaktiman-1	27.50	22.25	24.87
2.	Shaktiman-2	25.25	26.75	26.00
3.	Shaktiman-3	32.25	25.75	29.00
4.	Shaktiman-4	20.75	27.75	24.25
5.	Shaktiman-5	53.50	43.50	48.50
6.	Devaki	36.00	30.41	33.20
7.	Lakshmi (C) Resistant	19.75	16.75	18.25
8.	Suwan	26.75	24.25	25.50
9.	RHM-1	25.00	25.75	25.37
10.	RHM-2	57.50	48.00	52.75
11.	RHM-3	16.75	16.75	16.75
12.	Deep Jwala	17.00	18.75	17.87
13.	P-3535	28.75	26.00	27.37
14.	P-3533	23.50	21.75	22.62
15.	P-3550	49.00	47.00	48.00
16.	P-3555	37.50	37.50	37.50
17.	DeKalb 9188	42.75	41.00	41.87
18.	DeKalb 9170	29.75	25.65	27.70
19.	New Cross (76×11)	26.25	24.25	25.25
20.	New Cross (72×70)	16.00	16.25	16.12
21.	New Cross (73×11)	21.00	21.00	21.00
22.	New Cross (73×74)	18.75	18.97	18.86
23.	New Cross (52×65)	17.75	18.00	17.87
24.	New Cross (53×52)	27.75	26.25	27.00
25.	New Cross (50×58)	21.00	22.25	21.62
	CD ≤5%	2.58	2.15	2.31
	SEm (±)	0.89	0.77	0.78

Correlation between different traits

The results presented in Table 5, present correlation between different traits in which trichome density and different traits showed negative correlation while the correlation between trichome length and different trait was found to be positive. The maximum correlation was recorded between trichome length and infestation followed by trichome density and infestation per cent.

Discussion

Trichomes are hairy outgrowth of plant body surface that play a very important role in host plant resistance. Maize crop reported to be having non-glandular type of trichomes present over the plant surface but lower surface of leaves has less number than upper surface. In many cases, trichomes deter egg layings of insects. In the present experiment, all the genotypes found different degree of trichome density and some genotypes showed a greater number of trichomes (Table 2). Similarly, Harish (1997) have reported that "genotypes with a smaller number of trichomes, are able to support more larval population". All the assessed genotypes were lacking the trichome distribution on lower surface of leaves. It was assessed that with the increase in age, the number of trichomes were positively correlated and trichomes found to be maximum just before the tasseling stage. The distribution

Table 5. Correlation between different traits

S.No.	Trait A	Trait B	Correlation Value	Correlation
1.	Trichome Density	Infestation Per Cent	-0.451	Negative
2.	Trichome Density	Larval Survival	-0.397	Negative
3.	Trichome Density	Pupal Survival	-0.413	Negative
4.	Trichome Length	Infestation Per Cent	0.498	Positive
5.	Trichome Length	Larval Survival	0.411	Positive
6.	Trichome Length	Pupal Survival	0.473	Positive

of trichomes on leaves done by Munyiri *et al*. (2013) and they concluded that increasing the trichome numbers results in decreasing the infestation levels and established a negative correlation between trichome number and infestation. It was observed that the correlation between trichome number and infestation was negative significant (-0.451) which was in line with the stated findings.

It was observed that trichome length at one horizontal line of the leaf is larger on the distal end and middle of portion of leaves while apical portion of the plant has comparatively smaller trichomes. Smaller length of trichomes (Table 2) was more common in case of New Cross 76×11; 72×70 and New Cross 50×58 while RHM and Shaktiman Group found to be having longer trichomes. It was recorded that genotypes with larger trichomes are more infested in compare to genotypes having smaller length of trichomes and a positive (r=0.498) correlation (Table 2) has been observed between infestation and trichome lengths (All the promising genotypes and composites). Similarly, Harish (1997) reported that trichomes with larger lengths are less effective against neonate larvae in compare to short trichome hairs. They also have reported that distribution of trichomes on lower surface is rare.

Larval population intensity ranged from 0.25 to 4.75 larvae per plant and there was a significant difference has been recorded different genotypes (Table 3). Similarly, Kumar (1994); Bhoi *et al*. (2019); Rao and Panwar (2002) and many other workers have concluded in their work that significant number of larvae have been observed on the basis of various sets of trichomes distribution and length at the time of splitting after the tasseling stage.

Genotypes reported having maximum intensity of pupae had larger trichome lengths and lower density of trichomes. There is a significant similarity in pupal intensity was found between our results and work has been done previously by Kabre and Ghorpade (1999). Similar findings have also been concluded by many other workers including, Rao and Panwar (2002); Amjad *et al.* (2015). Genotypes like RHM-2 having more per cent infestation and the genotypes also showed more leaf injury score as well as all other parameters of infestation (Sekhon *et al*., 1992; Chaudhary and Sharma, 1992).

Conclusion

The study revealed that trichome density and infestation has a negative and significant association. It was observed that genotypes with higher trichom density, have lesser infestation of *C. partellus*. The genotypes with higher trichome density and lower infestation are, New Cross (72×70); Suwan; Deep Jwala; New Cross (53×52); DeKalb 9170; RHM-3; New Cross (52×65); New Cross (50×58); Shaktiman-4; P-3555; New Cross (76×11); New Cross (73×74); P-3533; Shaktiman-2. The trichome length seemed to have played a positive role in infestation as observed in genotypes namely, New Cross (72×70); Deep Jwala; New Cross (73×11); New Cross (73×74); RHM-3; New Cross (52×65); Devaki; P-3535; Shaktiman-5. Trichomes can inhibit infestation in many ways including inhibition of egg laying, restricting movement of neonate of *C. partellus.*

Acknowledgement

The author would like to thank to Dr. Ajay Kumar, Assistant Professor TCA Dholi for providing labour, seed of all the selected genotypes and area for growing the crop and Chairman Department of Entomology for their help during the research work.

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Maize Journal (October 2020) 9(2): 108-112

RESEARCH PAPER

Effect of babycorn intercropping with legumes on yield and profitability under rainfed condition

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Abstract: To explore the potential of babycorn and legume based intercropping systems a field experiment was conducted during *kharif* season of 2017 and 2018. The experiment was conducted with ten treatments *viz*. babycorn sole (60 × 15 cm), groundnut sole (30 × 10 cm), blackgram sole (30 × 10 cm), cowpea sole (30 × 30 cm), babycorn + groundnut (1:1), babycorn + blackgram (1:1), babycorn + cowpea (1:1), paired row of babycorn + groundnut (45/75 cm), paired row of babycorn + blackgram (45/75 cm) and paired row of babycorn + cowpea (45/75 cm) which were laid out in randomized block design with 3 replications. All the intercropping systems significantly influenced growth and yield attributing features of babycorn and paired row babycorn + groundnut intercropping system resulted higher number of pickings found at par with paired row babycorn + blackgram but statistically superior over rest of the treatments. Maximum babycorn yield (2252 kg ha^{-1}) was recorded under paired row babycorn + groundnut intercropping system found at par with paired row babycorn + blackgram (2095 kg ha^{-1}) but statistically superior over rest of the treatments whereas higher babycorn equivalent yield (2710.3 kg ha^{-1}) was obtained under paired row babycorn + groundnut intercropping system found at par with paired row babycorn + cowpea (2597.5 kg ha^{-1}) and paired row babycorn + blackgram (2520 kg ha^{-1}) but significantly superior over rest of the treatments. The highest net returns and B: C ratio ([1] 234228 ha^{-1} & 4.57) were recorded from paired row babycorn + groundnut found statistically at par with paired row babycorn + cowpea (₹ 221603 ha^{-1} & 4.44) and paired row babycorn + blackgram (₹ 215576 ha^{-1} & 4.30) but significantly superior over rest of the treatments. The results revealed that babycorn was more competitive with groundnut in paired row (2 + 2) having higher values of competitive ratio (4.74), babycorn relative yield (1.24), land equivalent ratio (1.90), area time equivalent ratio (1.39) and monitary advantage index (123754) followed by paired row babycorn + blackgram.

Keywords: Babycorn · Intercropping · Legumes · Profitability

Introduction

Recently specialty corn such as sweet corn, babycorn and popcorn has emerged as alternative food sources, especially for affluent society. Maize farmers are shifting towards specialty corn production because of higher net returns and also opening opportunities for employment generation mainly in peri-urban areas. With the increasing urbanization, changing food habit and the improved economic status, specialty corn (babycorn) has gained significant importance in urban areas of the country and because of that requirement of babycorn is increasing every year. There is lack of awareness among the farmers regarding quality for processing products which need to popularized for ensuring the livelihood security of rural masses and promotion of small-scale industry at rural level. Being a short duration crop (55 – 65 days), it easily fits

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Received: 20 April 2020/ Accepted: 21 July 2020

in rainfed cropping system and in addition it provides green, soft, succulent, nutritious, palatable fodder to cattle (Das *et al*., 2008).

As it is harvested at the time of silk emergence (without pollination) stage, so intercropping will provide substantial yield advantage over sole crop owing to temporal and spatial complementarily and minimizing inter- or intra-specific competition. In past, the importance of cereal intercropping with leguminous crops has been proved by many researchers due to complementary effect of each other on growth and quality of produce. For profitable and successful intercropping system, there must be suitable row ratio of component crop in order to escape limitation of reduced plants population of base crop under traditional intercropping system. There are many established and speculated advantages of intercropping systems such as higher grain yields, land use efficiency and better soil fertility by the component legume crops (Willey, 1979). The main advantage for the use of legumes in intercropping and mixed cropping is saving of N-fertilizer. To popularize maize and avoid competition with other crops, intercropping is a good technique where farmers can produce maize with other crops (pulses, oilseeds, vegetables etc.). Pulses can mobilize organic phosphorous in both soil cultures and hydroponic, leading to a site-specific facilitation in utilization of organic phosphorous in intercropping (Li *et al*., 2004). In the tropical and sub-tropical regions, cereal-legumes intercropping are the most popular practices because of many additional advantages (Willey, 1979). Intercropping becomes more productive and economic when both the crops differ with genetic makeup, photosynthetic pathway, growth habit, growth duration and demand of different growth resources.

Babycorn is latest introduction particularly as short duration crop; so efforts are required to standardize and economize its cultivation. Although the agronomic requirements like plant population and fertility levels (Dar *et al*., 2014), integrated nutrient management (Saha and Mondal, 2006) and weed control methods for babycorn have been worked out. Use of legumes as intercrops in babycorn not only manage weeds but also utilizes atmospheric nitrogen being fixed by it in the current growing season and helpful in residual nutrient build up in the soil. Higher corn yield due to the association of legumes, higher productivity and net returns from combinations of intercrops have also been reported by Patra *et al*. (2000).

Materials and methods

The field experiment was conducted during *kharif* seasons of 2017 and 2018 at the Research farm, Raj Mohini Devi College of Agriculture & Research Station, Ambikapur (Chhattisgarh), which is situated at 23^{o}10′N latitude, 83 ^{o}15′E longitude and at an altitude of 623 meters above the mean sea level. The soil of experimental field was sandy loam in texture with pH of 5.7, organic carbon 0.56 per cent, 234 kg/ha available N, 8.4 kg/ha P_2O_5 and 268 kg/ ha K_2O. The meteorological data recorded at meteorological observatory of the station indicated that rainfall received during the crop seasons was 1024.2 mm (46 rainy days) and 898.2 mm (41 rainy days) in 2017 and 2018, respectively. The experiment was laid out in randomized block design with three replications. There were 10 treatments, consisting of sole babycorn, sole groundnut, sole blackgram, sole cowpea, single row additive series (babycorn + groundnut, babycorn + blackgram and babycorn + cowpea) and paired row additive series ((babycorn + groundnut, babycorn + blackgram and babycorn + cowpea). The recommended doses of fertilizers were applied for sole and for intercrops as per row ratio. The recommended doses of fertilizers for babycorn were 150-80-60 kg N-P_2O_5- K_2O ha^{-1} and nitrogen as per treatment was applied in three splits. Half dose of nitrogen along with full dose of phosphorous and potassium was applied at the time of sowing of babycorn. The remaining dose of nitrogen was applied equally in two splits at 30 and 50 days after sowing. Full dose of nutrients 25-50-25 kg N-P_2O_5- K_2O ha^{-1} for groundnut and cowpea and 20-40-20 kg N-P_2O_5- K_2O ha^{-1} for blackgram were applied as starter dose at the time of sowing. Babycorn var Pro agro 4212, groundnut var Girnar 3, blackgram var PU-31 and cowpea var Ankur Gomati were sown during second week of July, 2017 and 18. Babycorn and intercrops (groundnut, blackgram and cowpea) varieties were sown manually at varying row spacing as per treatments. Gap filling and thinning were done within 10 days after sowing to maintain the optimum plant population. Weeds were controlled in babycorn by pre-emergence application of pendimethalin (1.5 l *a.i.* ha^{-1}). Detasseling was done just after tassel emergence to avoid fertilization. Five plants were tagged randomly from each plot for recording the growth and yield attributes. Immature baby cobs were harvested within 2-3 days after silk emergence and same were counted, weighed dehusked and babycorn yield was recorded. Standard yield of babycorn referred to those corn which were straight, having 7–10 cm length and 1–1.5 cm diameter mostly preferred for marketing purpose. The babycorn yield was calculated by adding the yield from all the pickings. Total green fodder yield was calculated by adding tassel weight, husk weight and green fodder weight of plants per plot at the time just after final pickings. Gross returns, net returns and benefit: cost ratios were calculated on the basis of prevailing market price of inputs and produce. To compute the productivity of system babycorn-equivalent yield (BCEY) was obtained by dividing the economic value of the produce (yield of produce x price of produce) with the price of babycorn. For calculating the babycorn equivalent yield, the prices of different crops were: babycorn (₹ 100/kg), groundnut (₹ 50/kg), blackgram (₹ 51/kg) and cowpea (₹ 20/kg). Economics of different treatments was worked out on the basis of prevailing market price. Competition functions like land equivalent ratio (LER), competitive ratio, area time equivalent ratio and monitory advantage index were computed as suggested by Patra *et al.* (1999). All data obtained in the inter cropping systems for 2 consecutive year of study were statistically analyzed using *F*- test, the procedure given by Gomez & Gomez (1984), critical difference (CD) values at P= 0.05 were used to determine the significance of differences between means.

Results and discussion

Yield attributes

Different intercropping systems significantly affected the yield attributes of babycorn (Table 1). Higher yield attributes, *viz* length and girth of babycorn and number of pickings were recorded under paired row babycorn + groundnut found at par with paired row babycorn + blackgram and babycorn sole but significantly superior over paired row babycorn + cowpea, single row babycorn + groundnut, single row babycorn + blackgram and single row babycorn + cowpea.

Different intercropping systems significantly affected the yield attributes of intercrops (Table 1). Higher yield attributes of groundnut, *viz* number of pods plant^{-1} and number of kernels pod^{-1} were recorded under sole groundnut followed by paired row babycorn + groundnut and single row babycorn + groundnut. In case of blackgram, higher yield attributes, *viz* number of pods plant^{-1}, length of pods and number of seeds pod^{-1} were

Table 1. Effect of different intercropping systems on yield attributes of babycorn and intercrops (mean data of 2 yrs)

Treatments	Yield attributes of babycorn			Yield attributes of intercrops						
				Groundnut		Blackgram			Cowpea	
	Length of Babycorn (cm)	Girth of Babycorn (cm)	No of pickings	No of pods plant^{-1}	No of kernels pod^{-1}	No of pods plant^{-1}	No of seeds pod^{-1}	Length of pods (cm)	No of pods plant^{-1}	Length of pods (cm)
Babycorn sole (60 × 15 cm)	8.78	2.86	2.30	-	-	-	-	-	-	-
Groundnut sole (30 × 10 cm)	-	-	-	15.3	2.6	-	-	-	-	-
Blackgram sole (30 × 10 cm)	-	-	-	-	-	18.3	6.9	4.4	-	-
Cowpea sole (30 × 30 cm)	-	-	-	-	-	-	-	-	8.2	24.5
Babycorn + Groundnut (1:1)	8.16	2.75	2.17	11.4	2.2	-	-	-	-	-
Babycorn + Blackgram (1:1)	7.82	2.49	2.13	-	-	16.9	6.4	4.1		
Babycorn + Cowpea (1:1)	7.49	2.23	2.04	-	-	-	-	-	5.5	17.5
Babycorn + Groundnut (2:2) (45/75 cm)	9.31	3.00	2.57	13.5	2.4	-	-	-	-	-
Babycorn + Blackgram (2:2) (45/75 cm)	8.60	2.89	2.43	-	-	18.0	6.5	4.2		
Babycorn + Cowpea (2:2) (45/75 cm)	7.82	2.57	2.24	-	-	-	-	-	6.9	21.8
SEm±	0.44	0.21	0.10	-	-	-	-	-	-	-
C.D. (P=0.05)	1.36	0.63	0.31	-	-	-	-	-	-	-

recorded under sole blackgram followed by paired row babycorn + blackgram and single row babycorn + blackgram whereas yield attributes of cowpea *viz* number of pods plant^{-1} and length of pods were higher under sole cowpea followed by paired row babycorn + cowpea and single row babycorn + cowpea.

The increased in yield attributes of babycorn might have occurred owing to the improved due to symbiotic nitrogen fixation by legumes and its subsequent transfer to babycorn which was also evident from the higher growth attributes. The more congenial environment under paired row planting might have increased the babycorn to avail the natural resources like soil, water and light which might have resulted in taller plants and ultimately more dry matter accumulation and yield attributing features. In case of intercrops, higher yield attributes were recorded under sole crops due to higher competition for natural resources both under single and paired row intercropping system. Similar results were also reported by Solanki *et al*. (2011).

Babycorn equivalent yield

Intercropping systems had significant influence on babycorn and babycorn equivalent yield (Table 2). Significantly maximum babycorn equivalent yield was recorded under paired row babycorn + groundnut (2710 kg ha^{-1}) was statistically comparable with paired row babycorn + cowpea (2597 kg ha^{-1}) and paired row babycorn + blackgram (2520 kg ha^{-1}) but significantly superior over rest of the treatments. However, among single row intercropping system, single row babycorn + cowpea recorded maximum babycorn equivalent yield (2208 kg ha^{-1}) found statistically comparable with single row babycorn + groundnut (2139 kg ha^{-1}) and single row babycorn + blackgram (2000 kg ha^{-1}). Paired row babycorn + groundnut which were 49.74 per cent higher over babycorn sole (1810 kg ha^{-1}) whereas paired row babycorn + cowpea had babycorn equivalent yield (2597 kg ha^{-1}) and paired row babycorn + blackgram had babycorn equivalent yield (2520 kg ha^{-1}) which was 43.51 per cent and 39.22 per cent higher over babycorn sole.

The increase in yield of babycorn, intercrop yield and babycorn equivalent yield might have occurred owing to the improved due to symbiotic nitrogen fixation by legumes and its subsequent transfer to babycorn which was also evident from the higher growth attributes. Babycorn in paired rows intercropped with legumes

Table 2. Effect of different intercropping systems on babycorn equivalent yield, competition functions, net return and B:C ratio (mean data of 2 yrs)

Treatments	Babycorn equivalent yield (kg ha^{-1})			Competitive ratio		Land equivalent ratio	Area time equivalent ratio	Monitary advantage index	Net return (₹ ha^{-1})	B:C ratio
	Babycorn	Intercrops	Total	Babycorn	Intercrops					
Babycorn sole (60 × 15 cm)	1810	-	1810	-	-	-	-	-	152503	3.78
Groundnut sole (30 × 10 cm)	-	813	813	-	-	-	-	-	44756	1.22
Blackgram sole (30 × 10 cm)	-	766	766	-	-	-	-	-	42870	1.27
Cowpea sole (30 × 30 cm)	-	1554	1554	-	-	-	-	-	119123	3.29
Babycorn + Groundnut (1:1)	1747	393	2139	3.22	0.65	1.45	1.08	63747.5	174942	3.46
Babycorn + Blackgram (1:1)	1637	364	2000	3.06	0.62	1.38	0.92	54985.3	161826	3.28
Babycorn + Cowpea (1:1)	1487	721	2208	2.86	0.58	1.29	0.75	49075.6	181455	3.69
Babycorn + Groundnut (2:2) (45/75 cm)	2252	458	2710	4.74	0.76	1.90	1.39	123753.7	234228	4.57
Babycorn + Blackgram (2:2) (45/75 cm)	2095	425	2520	4.28	0.68	1.71	1.14	104831.0	215576	4.30
Babycorn + Cowpea (2:2) (45/75 cm)	1734	863.0	2597	3.78	0.61	1.51	0.88	88155.2	221603	4.44
SEm±	104.5	23.8	86.1	-	-	-	-	-	8992	0.20
C.D. (P=0.05)	322.2	70.7	255.8	-	-	-	-	-	26718	0.59

registered higher growth characters, dry matter accumulation and yield attributes and yield. Added to this the intercrop yield which is the bonus and converted to babycorn equivalent yield and the total yield of babycorn and the total yield of babycorn and babycorn equivalent yield of the intercrops was higher. Similar results were also reported by Shyamal *et al.* (2013).

Competition functions

Babycorn was more competitive with groundnut in paired row (2 + 2) having higher values of competitive ratio (4.74), babycorn relative yield (1.24), land equivalent ratio (1.90), area time equivalent ratio (1.39) and monitary advantage index (123754) followed by paired row babycorn + blackgram (Table 2). The highest area time equivalent ratio (1.39) of the system established that growth requirement of both component crops differs in time, resulting higher per day yield of the system due to temporal complemented effect. The highest value of monetary advantage index of the system established it (T_8) as most remunerative owing to higher babycorn equivalent yield of the system. These results are close conformity with Padhi and Panigrahi (2006).

Economics

Intercropping groundnut, blackgram and cowpea with babycorn at single row (1:1) and paired row (2:2) established a definite increase in net return and benefit: cost ratio over their respective monoculture of component crops (Table 2). Net return was significantly affected due to various intercropping treatments. Maximum net returns and benefit: cost ratio were obtained under paired row babycorn + groundnut which was on par with paired row babycorn + cowpea and paired row babycorn + blackgram and these intercropping systems were significantly superior over rest of the treatments. The practical utility of any treatment can be best judged because of net return and benefit: cost ratio. Paired row babycorn + groundnut had higher net return and benefit: cost ratio found statistically comparable with paired row babycorn + cowpea and paired row babycorn + blackgram and all these treatments provided more net return and benefit: cost ratio then other treatments. This was because of more net returns than the money spent in crop production under these treatments. These results are found to be in close conformity with Upasani *et al.* (2017).

From this study it may be inferred that raising paired row babycorn + groundnut (2:2) found comparable with paired row babycorn + cowpea (2:2) and babycorn + blackgram (2:2) proved most compatible, economically viable and superior to their (1:1) intercropping systems as well as sole planting for getting higher yield and net return.

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Maize Journal (October 2020) 9(2): 113-124

RESEARCH PAPER

Effects of farmers' knowledge, attitude and skills on highland maize adoption in western Ethiopia

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Abstract: Understanding farmers' indigenous knowledge is important in hybrid maize popularization. Despite different opportunities, adoption was constrained by failure of infusing local knowledge in modern extension system. Hence, farmers' capabilities, preferences and practices towards adoption was studied. Data were collected from key informants and participants of focus group discussion. Cross-sectional survey was conducted to collect data from 154 respondents. Knowledge and attitude were assessed by using 5-point Likert scale. Descriptive statistics and econometric analysis were done to analyze data accordingly. Among demographic characteristics; family and land size, owning of ox and experience has positively affected highland maize adoption at 1 per cent significance level; while education, age, and on-farm income has positively affected highland maize adoption at 1% significance level. But religion and sex didn't affect highland maize adoption at all. Pearson chi-square result indicated, there was positive and significant relationship of knowledge (χ^2 = 41.49) to adoption. Consequently, increase in farmers' Knowledge favored adoption or institutional support, insufficient involvement of resource poor farmers and lack of trainings were major bottlenecks hampering highland maize adoption. Hence, provision of special training, credit services and farmers-responsive training should be in place for better adoption.

Keywords: Adoption · Ambo · Binary logit · Knowledge-Attitude-Skill · Maize

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Received: 03 August 2020/ Accepted: 11 November 2020

Introduction

Maize (*Zea mays* L.) is one of the most important cereal grains grown worldwide. It is the third major cereal crop mainly used as a food source and now has become the most important raw material for animal feed. Maize is the second most important crop in Ethiopia (Anley *et al.*, 2013; CSA, 2015; Smale, 1995). By contributing 31 per cent of grain production, maize production in sub-Saharan Africa is predicted to double in 2050. The crop contributes 15 per cent of world's protein and 19 per cent of calories. Hence, millions of people in Ethiopia depend on it for protein and daily calorie requirements (Mbuya *et al.*, 2011; Vasal, 2002). Consequently, owing to its wider cultivation, maize received highest attention of all food crops under extension program in Ethiopia (Kafle, 2010; Monela, 2014).

Of the 22 countries in the world where maize forms the highest percentage of calorie intake in national diet, 16 are in Africa; where regional average yields are as high as 1.7 t/ha in West Africa and 1.5 t/ha in East Africa, and 1.1 t/ha in Southern Africa (Smale *et al.*, 2011). Even though Ethiopia with >3 t/ha have made significant productivity gains, the average yield of maize is still far below the global average yield of maize (5.5 t/ha) and considerably below the 4.4-5.4 t/ha on-farm trial results of improved varieties under optimal inputs and improved management conditions undertaken by CIMMYT in Sub-Sharan Africa.

Adoption of improved maize hybrids in developing countries has been constrained by failure of inculcating indigenous knowledge, skill and attitudes in the modern extension system. In Kenya, though the area devoted to maize production and income generated from maize is increasing, the status of production of hybrid maize is still lower than the open pollinated varieties (Tiwari *et al.*, 2004).

Differences in farmers' cognitive ability, attitudes and perceptions across locations have greatly influenced farmers' decisions on adoption of technologies (Jain, 2007; Power *et al.*, 2013). This in turn, forced farmers to cast-off adoption of improved maize varieties; which sequentially resulted in information gap among them. According to Demissew *et al.* (2012), improved maize varieties in Ethiopian highland farmers were not well popularized and therefore great differences is portrayed in adoption of improved maize varieties which brought large differences in yield per unit of land areas (Cheesman *et al.,* 2017).

Advanced knowledge about agricultural technologies commonly drives policy reform and leads to change if only reinforced with apt contexts of remedies. Nevertheless, until recently there are research and development efforts becoming futile due to limitation of inculcating farmers' knowledge, attitude and perceptions on highland maize adoption schemes. Hence, interventions made so far were so scarce and even these were infertile. It also lacks collaborative linkage among stakeholders to bring about desirable effects.

The, Farmers' Knowledge, Attitude, Skills (KAS) on maize adoption was given little attention in the study area. Hence, farmers' capabilities, preferences, practices and reactions towards the technology needs to be explicitly studied to ameliorate farmers' awareness and productivity towards improved agricultural technologies in Ethiopia, among other things. This would be practical if gaps on KAS were identified and due consideration was given to farmers' felt needs and interests. Hence the overall objective of this research is to analyze effects of farmers' knowledge, attitude, skills and determinants on highland maize adoption in the study areas.

Materials and methods

Description of the study area

The study was conducted in Ambo district of Western Oromia of Ethiopia; and location lies between latitude and longitude of 8°59′N and 37°51′E, respectively. Its elevation ranges from 1380 to 3030 meter above sea level. Ambo district is bordered on West by Toke Kutaye, on North by Elfeta and Jeldu, on East by Dendi, and on South by Toke Kutaye, Wenchiand Southwest Shewa Zone (CSA, 2013). The district is administratively divided into 33 *kebele* and has three town *kebeles*. Kebele is the smallest administrative sell in Ethiopian public governance.

Sampling techniques and sample size determination

Multistage sampling employed to select respondents where first, Western Shoa Zone was selected purposefully due to agro-ecological suitability of highland maize. After excluding lowland areas, 14 high and mid altitud*e kebeles* were selected purposefully at second stage. Three kebeles were randomly selected (out of 14) by using simple random sampling since the technique gives equal chance of selecting locations. Then, at fourth stage, Slovene's sample size determination formula (Altares *et al.,* 2003; Ellen, 2012) was used to determine number of adopters' sample size:

$$n = \frac{N}{1 + Ne^2}$$

Where, n is expected sample size

N is total population

e = error term at 95 per cent confidence level which makes the total sample size 64.

Subsequently, by using probability proportional to size (PPS) at fifth stage, proportional sample size of adopters and non-adopters for each Kebele was set accordingly to determine number of total respondents from the three kebeles. Finally, by using sampling frame collected from each Kebele Administrations, systematic random sampling was used to select actual respondents (Table 1).

Types of data and methods of collection

Before conducting cross-sectional exploratory survey, preliminary survey was conducted to develop workable hypothesis. For this, three focus group discussions were held with groups of farmers. Similarly, 15 key informants were involved in discourses made with government officials, chairpersons, local farmer leaders and elders to generate qualitative data.

KAS survey was employed to identify knowl-edge gap and behavioral pat-terns that facilitate/hinder acquaintance, action and bar-riers on highland maize adoptions. For this five-point Likert-scale. was used to analyze extent of

Table 1. Summary of sample size from each *Kebeles*

Selected *Kebeles*	Adopter			Non-adopter			Total
	M	F	Total	M	F	Total	
Gosu Kora	24	11	35	35	15	50	85
Bilo	12	5	17	17	7	24	41
Boji Gebisa	8	4	12	11	5	16	28
Total	44	20	64	63	27	90	154

respondents' degree of agreement of choice with each question. Then, results were transformed to dichotomous variable. Semi-structured interview schedule was used to collect data from cross-sectional survey.

Methods of data analysis

Quantitative data were computed by using descriptive statistics were run by using SPSS version 20; while MS-Excel 2016 was used to narrate and describe qualitative data. Binary logistic regression was run to identify determinants of farmers for adopting highland maize econometrically.

Results and discussion

Farmers' knowledge

Pearson chi-square result indicated there was positive and significant relationship of knowledge (χ^2 = 41.49; p = 0.001) with adoption. Though knowledge level of both adopters and non-adopters was low, adopters were better off to their counterparts (more than two folds). Hence, adopters were better in knowledge and thus showed better tendency to utilize the technology.

Attitude of farmers

The relationship between adoption and attitude was positive and significant at 5% (χ^2 = 25.23; p = 0.032). This result was also supported by chi-square result, which showed farmers showed positive feelings not only for highland maize in question but also to extension agents who brought the technology to the farmer. The outcome was further reinforced by Focus Group and Key informant participants who felt positive psychological tendency to highland maize than their complements. However, this chance was not fully exploited by formal extension services due to imperiling outlay which impoverished farmers not to practice the technology further.

Skill of farmers

Respondents' practice on highland maize showed, 36.4 per cent of adopters and 22.7 per cent of non-adopters exercised improved maize technology. The chi-square result supported there had been positive and significant relationship between skill and highland maize adoption (χ^2 = 36.56; P = 0.000) at P <0.01 (Table 2). Hence, as farmers' practice increases, adoption of high land maize varieties had augmented, adoption was getting better.

Table 2. Distribution of adoption category of farmers

Variable	Category	Non-adopter		Adopter		Total		χ^2-value	P-value
		N	%	N	%	N	%		
Knowledge	Not know	67	43.5	14	9.1	81	52.6	41.46	0.001***
	Know	23	14.9	50	32.5	73	47.4		
	Total	90	58.4	64	41.6	154	100		
Attitude	Negative	58	37.7	15	9.7	73	47.4	25.23	0.032**
	Positive	32	20.8	49	31.8	81	52.6		
	Total	90	58.4	64	41.6	154	100		
Skill	No skill	55	35.7	8	5.2	63	40.9	36.56	0.054*
	Have skill	35	22.7	56	36.4	91	59.1		
	Total	90	58.4	64	41.6	154	100		

Demographic factors influencing farmers adoption

Among different variables, family size, land size, owning of ox and experience has positively affected highland maize adoption while education level, age, and income earned from crop and livestock has positively affected highland maize adoption at 1 per cent significance level. But being follower of any religion and sex didn't affect highland maize adoption at all.

Age of respondents

Households age, continuous variable measured in number of years, positively affected maize adoption at P<0.05 (Mean = 38.83; standard deviation = 10.13). Similarly, t-test result showed data set were farther from the mean by +8.56 years. This implied, there was significant associations of age with adoption since data were not concentrated around the mean i.e. 38.83 years. (t = 8.56, p = 0.032).

The minimum and maximum age of household heads was 25 and 84 years (Table 3) and majorities of household heads were ranged in active/ productive age group (15 to 60 years old). The normal curve on histogram showed adoption was increasing to maximum at earlier age of respondents then it started to decline the total mean age of respondents (Figure 1) conforming the result that youngsters were more inclined to adoption.

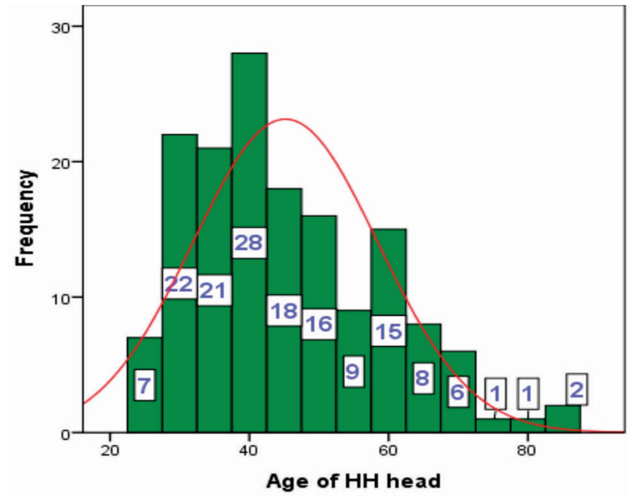

Figure 1. Frequency distribution of age of household heads in highland maize adoption.

Experience

Respondents practice which was continuous variable measured in number of years has positively affected adoption at P<0.01 (Mean = 3.21 years and SD of 3.37). But 41.1 per cent of non-adopters didn't have highland maize farming experience at all, implying that they rejected highland maize.

Education status

The relationship between education to adoption indicated that most of non-adopters (45.45%) were less involved

Table 3. Descriptive Statistical result of demographic and institutional characteristics

Variable	Category	Non-adopters (n = 90)		Adopters (n = 64)		Total (n = 154)		χ^2	P-value
		N	%	N	%	N	%		
SEX	Female	27	17.5	21	13.6	48	31.2	0.138NS	0.710
	Male	63	40.9	43	27.9	106	68.8		
Membership	No	16	10.4	6	3.9	22	14.3	2.157NS	0.142
	Yes	74	48.1	58	37.7	132	85.7		
Credit service	No	89	57.8	58	37.7	147	95.5	5.887	0.015**
	Yes	1	0.6	6	3.9	7	4.5		
ICT use	No	54	35.1	8	5.2	62	40.3	35.087	0.000***
	Yes	36	23.4	56	36.4	92	59.7		
Perceived risk	No	75	48.7	38	24.7	113	73.4	10.990	0.001***
	Yes	15	9.7	26	16.9	41	26.6		
Maize taste	Bad	45	29.2	6	3.9	51	33.1	27.869	0.000***
	Good	45	29.2	58	37.7	103	66.9		

in formal education and thus it could be pronounced that lack of involvement in formal education deterred non-adopters to get involved in adoption. Nevertheless, comparatively, most adopters have joined formal education than their counterparts since only 22.94 per cent were refrained from classes while the rest joined formal educations. Accordingly, better entitlement to education ameliorated adoption (p = 0.003). Hence, the ability to acquire new information and determining readiness of household heads through education played significant role in improving innovations and willingness to participated of highland maize adoption (Figure 2).

Family size

With average family size of 4.43 and 5.84, non-adopters had lower family size than adopters. Correspondingly, mean family size of non-adopters was less than national average; which was five. The result implied, better availability of active labor force in for adoption process. The minimum and maximum family sizes of household were 1 and 17; and the total mean and SD was 5.13 (4.81), while mean and SD of adopters and non-adopters were 5.84 (5.11) and 4.43 (4.52), respectively. Thus, the statistical values (t=5.63; p = 0.000) showed that there was significant mean difference between the family size and adoption of highland maize. Hence, a number of family members living in the household head was responsible for farm activities as input, and plays a role in highland maize adoption in study areas.

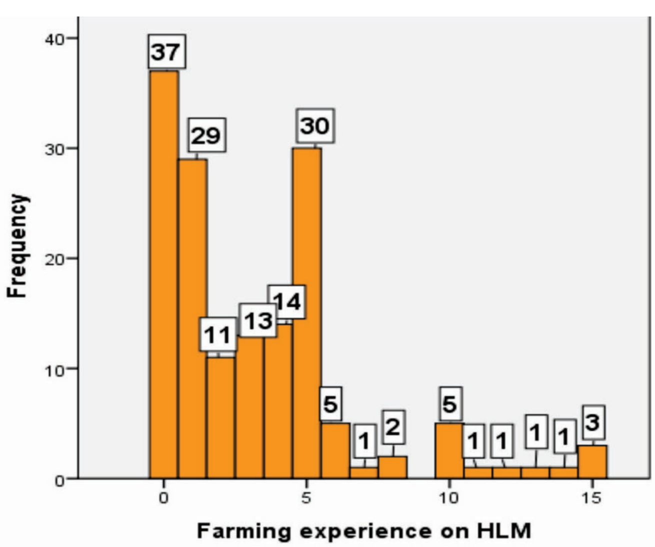

Figure 2. Frequency distribution of farming experience (Year) by household heads

Sex of household heads

Distribution of highland maize adoption by different sex of households showed, 68.8 per cent total male respondents took larger proportion than females (Table 4). Therefore, the result clearly showed existing gap between male and female household heads in terms of involvement in adoption. However, Pearson chi-square test indicated that sex of household heads had no significant relationship (χ^2 = 0.14, p = 0.71) with highland maize adoption. This would be because of smaller number of female household heads and high proportion of non-adopters.

This result was in line to Anikand Salam (2015) who reported prevailing social set up of rural households placed a varying responsibility among male and female members. In most parts of rural Ethiopia women were disfavored groups of the society who couldn’t easily access technology information. Thus, numerous adoption studies had come up with results showing being a female headed negatively influencing technology adoption decisions. Consequently, those male headed households who have more access to information to use innovation than female-headed households, which have a capacity to influence by the cultural norms and traditions.

Institutional factors

Land size

The total mean land size used for the highland maize cultivation was 0.21 ha with SD of 0.20. This nearly resembled with average highland maize land coverage (0.25 ha) responses obtained during focus group discussions and key informant discussions in each kebele (Table 4).

From non-adopter and adopter categories, mean and standard deviation values for adopters and non-adopters was 0.32 (0.184) and 0.13 ha (0.18), respectively. Besides, the results of t-test value (t=6.38) and P-value (p = 0.000) showed statistically significant mean difference in land size between both adoption categories implying the larger the size of cultivated land of highland maize, the greater would be its adoption.

Ownership of ox

Ownership of ox (Tropical Livestock Unit) has been important source of draft power and major means of

Table 4. General characteristics of sample respondents in the study area

Characteristics	Min.	Max	Non-adopters	Adopters	Total	χ^2-or t-test	P value
			Mean (SD) (N=90)	Mean (SD) (N=64)	Mean (SD) (N=154)		
Age of household head	25	84	42.48 (12.94)	35.17 (7.32)	38.83 (10.13)	8.56	p=0.031**
Family size	1	17	4.43 (4.52)	5.84 (5.11)	5.13 (4.81)	5.63	p=0.000***
Education level	0	12+3	Mean (%)	Mean (%)	Mean (%)		
Illiterate			45.45	22.94	34.19	15.94	p=0.003***
Read and write			25.21	28.59	26.91		
Primary school			17.22	29.28	23.25		
Post primary			12.12	19.19	15.65		
Land size	0	1	0.13 (0.18)	0.32 (0.18)	0.21 (0.20)	6.382	0.000***
Ox own	0	8	1.92 (1.01)	2.80 (1.31)	2.29 (1.22)	4.477	0.002***
Experience	0	15	1.44 (2.13)	5.69 (3.25)	3.21 (3.37)	9.144	0.000***
Annual Family Income			Mean (SD)	Mean (SD)	Mean (SD)		
Crop (USD/family)	370	5000	957 (22.78)	1245 (15.37)	1010 (19.02)	32.54	p=0.01**
Livestock (USD/ family)	110	1200	742 (2.52)	1095 (21.74)	918 (11.56)		
Religion			Mean (%)	Mean (%)	Mean (%)		
Orthodox			43.24	45.34	44.31	29.26	p=0.4
Muslim			26.63	27.27	26.95		
Protestant			17.92	17.15	17.5		
Others			12.21	10.24	11.23		
Marital status			Mean (%)	Mean (%)	Mean (%)	22.26	
Single			15.61	12.45	14.02		p=0.07*
Married			57.01	52.31	54.65		
Divorced			17.15	24.23	21.21		
Widowed			10.23	11.01	10.52		

Source: Survey result, 2019; Own computation, 2019

tillage or land cultivation in the study district. The result of this study indicated in (Table 4) that minimum and maximum oxen ownership among respondents ranged from zero to eight respectively. The total was found 2.29 TLU with SD of 1.22 for all household heads. It was observed that the non-adopters had mean of 1.76 TLU and SD of 1.27, whereas the adopters had mean of 2.89 TLU and SD of 1.83. The statistical t-test values (t = 4.29; p = 0.002) also showed that there had been significant difference in ox ownership of non-adopters and adopters of highland maize, indicating strong association (at less than 1% probability status) in between them. Household heads who have a pair of oxen (in extra number) would adopt the technology as compared with those have one or have not any ox. However, owning ox/oxen alone wouldn’t draw the attention of farmers to adopt highland maize. There would be awareness creation, raise or applicable demonstration activities as interventions about benefits of the technology improving the available resources.

Highland maize related institutional variables include membership to organization, highland maize extension service access, highland maize credit access, and use of ICT among respondents. Being member of a group with particular purpose and socializations brought households together mainly for benefits of farming activities. Being membership, helped in information sharing and building mutual trust and bondage among the households in the study district. In this study, the frequency distribution of total member household heads, 85.7 per cent took larger

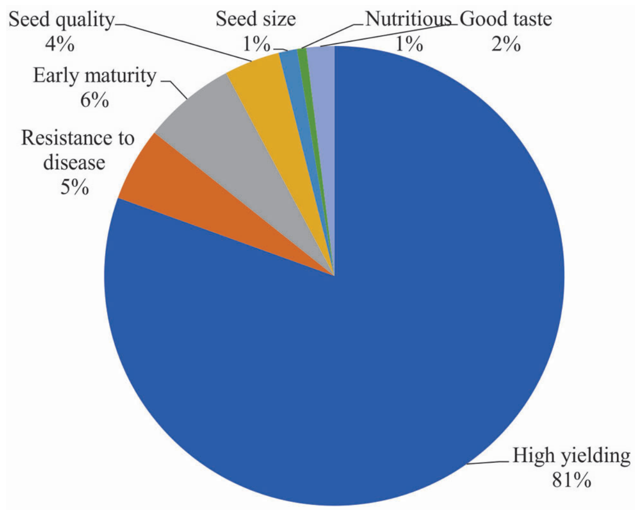

Figure 3. Major criteria for preferring the highland maize by respondents

proportion than nonmembers, 14.3 per cent in highland maize adoption (Table 5). The proportions of non-members were relatively high within non-adopter groups 10.4 per cent than within adopter groups 3.9 per cent. The majority (48.1 per cent) of non-adopters were members at least in one of organizations the area. However, the result clearly showed existing gap between members (high) and non-member (low) households had been not worth mentioning for adoption. Thus, calculated values ($\chi^2 = 2.157$; $p = 0.142$) indicated household heads' membership of organization had no significant relationship with adoption of highland maize statistically in both categories.

Different institutions have been arranging variety of extension services or events (trainings, on/off-farm demonstrations, field days/visits, and others) relating to highland maize. These have been some of the means through which the surrounding farmers are getting highland maize information and access in the area. Respondents' highland maize extension service access is the derivative of access to institutional services. The result showed 53.2 per cent household heads have extension access related to highland maize while 46.8 per cent did not get the service. Similarly, 29.9 per cent of adopters had extension service access to highland maize; whereas the rest 11.7 per cent did not get the service. The highest number 35.1 per cent did not access to extension services and 23.4 per cent directly shared the service.

Credit

The existence of and affordability of formal highland maize related credit at least as entry became a central service to solve financial constraint of the pro-poor rural households. It plays a significant role in income diversification, upgrading highland maize adoption status, in turn, positively influencing its production and productivity. The availability of improved highland maize -specific credit service (in kind) usually on inputs required (during off-farm demonstrations, trials e.g. for PVS) had been observed irregularly on some selected highland maize producers as payback and motivation. The Focus Group Discussions and Key informant discussions sessions' results also verified that, few respondents had received a kind of credit services in terms of seed, chemical fertilizers and pesticides from other projects too, highland maize research and extension case teams. Actually, there was no significant, functional and formal highland maize credit service provider report in the area during the study. As indicated in (Table 6), almost all sampled respondents,

Table 5. Descriptive statistical summary of continuous explanatory variables

Variables	Non-Ad (n=90)	Adopter (n=64)	t-value	P-value
	Mean (SD)	Mean (SD)		
Age of household heads	46.46 (13.89)	43.36 (12.24)	1.462NS	0.146
Education status of household heads	3.50 (3.30)	5.59 (3.76)	3.580	0.001***
No. of persons in family	1.76 (1.27)	2.89 (1.83)	4.268	0.000***
Cultivated land size owned	0.13 (0.181)	0.323 (0.184)	6.382	0.000***
No. ox owned by household head	1.92 (1.01)	2.80 (1.31)	4.477	0.002***
Total asset owned at household head	605.59 (988.66)	750.375 (1420.90)	0.703NS	0.484
highland maize grain av. yield	2112 (25.49)	3338 (17.26)	3.556	0.001***
Farming experience in year	1.44 (2.13)	5.69 (3.25)	9.144	0.000***

***Means significant at 1% probability status; SD = Std Deviation

95.5 per cent reported that there was no permanent highland maize credit way in the area while only the remaining, 4.5 per cent respondents accessed to highland maize credit (supply in kind) in the study area. With respect to the credit accessibility, 0.6 per cent non-adopter and 3.9 per cent adopters had kind of credit for highland maize production. Because of these on-adopters, especially the pro-poor would become nonusers of the technology. Similarly, the statistic values (χ^2 = 5.887, P = 0.015) showed access to highland maize credit service had positive and significant relationship between the two adoption categories which found nearly at 1 per cent probability status. Credit access to highland maize can be taken as a proxy indicator for adoption of technologies expressly for the pro-poor rural household heads farmers at local levels (Figure 4).

The result showed that majority of sample respondents, 73.4 per cent had perceived risks in production of highland maize. Out of this, 48.7 per cent were non-adopters and 24.7 per cent were adopters. The number of respondents who did not relatively perceive risks were 9.7 per cent from non-adopters and 16.9 per cent from adopter categories. These imply that attention should be paid to the perceived risks identified to consider the high proportion of non-adopters to be beneficiaries. Thus, the statistic calculation values (χ^2 = 10.990; p = 0.001) showed that perceived risks during highland maize production had significant relationship with both adoption categories which found at less than 1 per cent probability status (Figure 5).

Four explanatory variables (sex of household heads, Member of any organ, Inter/intra household head, age and

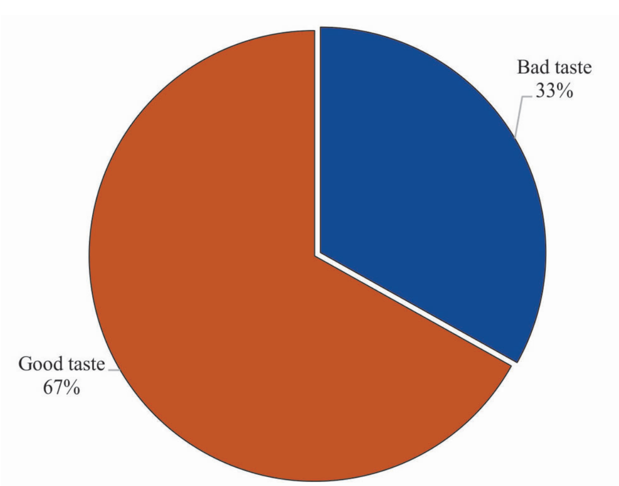

Figure 4. Taste of highland maize flavor by household heads in the study area

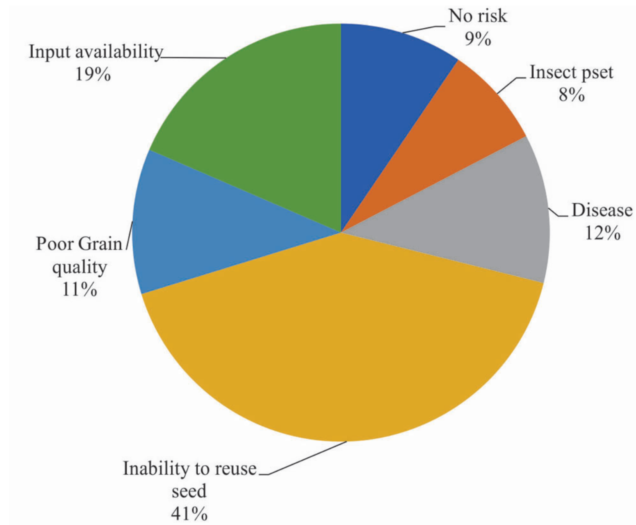

Figure 5. Risks observed by respondents in last year of cropping season

Total asset owned at household head) showed statistically insignificant relationship. In all of explanatory variables described, the intervening or confounding variables (KAS) have been identified as causes in the adoption processes. T-test result showed that, mean and SD of all continuous variables of adopters have were greater than non-adopters; whereas, categorical variables were in favor of adopters' category, except credit. These would clearly imply that KAS is playing pivotal role in highland maize adoption.

Econometric analysis of binary logistic regression

Among 15 independent variables which were proposed to influence adoption, only eight predictors *namely: sex of household heads, family size, ox ownership, estimated asset ownership, access to extension service, and use of ICT, perceived risk, and farming experience of household heads* were found significant.

Sex

Probability of being male household head positively influenced adoption by factor of 3.58 than women counterparts at P<0.01 taking all other variables constant. It is likely due to that women hardly adopted highland maize since male household heads usually take high share of resources in the study area. Men household heads had direct significant influence on highland maize adoption.

The result was in line to Christina *et al.* (2001); Tshiunza *et al.* (2001); Muche *et al.* (2014) who reported sex of household head is positively associated with control over resources and technology adoption. Male is in a better position to pull labor force as compared to household heads. Females often lack labor, rent their land on share cropping basis. Further, Abdi (2015) indicated being male increases participation in irrigation activities positively.

Total family size

The model showed family size had positive and significant result at P <0.05. The absence of negative sign in the model was indication of high probability of being highland maize adopted with increased number of family size in favor. Odds ratio of highland maize adoption was 1.72 indicating as number of household head family size increased by one-unit adoption had increased by 1.72 unit. This implies increasing family size brought ameliorating effect on highland maize adoption.

The finding was well supported by Feder *et al.* (1985); Awotide *et al.* (2016) who reported favoring effect of large family size on adopting technologies. But, contrary with findings of Ayalew (2003), Tesfaye (2005), Guled (2006) and Mequanent (2009) that resulted in households with large family size, composed mainly of non-productive population could face probability to be food insecure due to high burden levied on active labor. An increase in household head size implies more mouth to be fed from limited resources and has negative relationship with food security.

Number of oxen ownership

It was one of wealth accumulation scheme in rural areas and as expected, number of ox ownership brought positive and significant influence on highland maize adoption at 5% significance level. The model output on Exp (B) revealed as oxen ownership of household heads increased by one unit (TLU), probability of highland maize adoption increased by factor of 2.06. This implied, owning oxen power allowed valuable use of resources (diversifying land, labor), and it is means to cultivate land traditionally.

The finding was in line to Tesfaye (2005); Guled (2006); Mequanent (2009); Muche *et al*. (2014); Taruvinga *et al.* (2013); Megersa *et al.* (2014); Workicho *et al*. (2016), who reported positive association of livestock ownership in moving dietary status of diversifications.

Total volume of estimated asset ownership

It was hypothesized to have positive influence on highland maize adoption in the study area. According to logit result,

Table 6. Binary logit model output of the independent variables set on highland maize adoption

Variable	β	S.E.	Wald	Sig.	Exp (B)
Sex of household heads	1.27	0.75	2.85	0.091*	3.581
Age of household heads	-0.01	0.03	0.21	0.646^{NS}	0.986
Education status	0.01	0.09	0.01	0.898^{NS}	1.012
No. of persons in family	0.54	0.30	3.20	0.073**	1.723
highland maize cultivated land size at household head	2.80	2.07	1.79	0.181^{NS}	16.004
No. ox owned by household head	0.73	0.38	3.61	0.057**	2.068
Total asset owned at household head	0.00	0.00	3.52	0.060**	1.000
Member of any organization inter/intra household head	1.57	1.26	1.53	0.215^{NS}	4.822
Access to extension services	1.85	0.77	5.71	0.017***	6.328
Credit service existence	0.73	2.67	0.07	0.786^{NS}	2.065
Use of ICT by farmers	2.67	0.84	9.88	0.002***	14.366
Perceived risks: threat, constraint	1.97	0.71	7.50	0.006***	7.154
highland maize grain av. yield	0.00	0.00	1.05	0.303^{NS}	1.000
highland maize taste on preference	0.25	1.01	0.06	0.804^{NS}	1.286
Farming experience in year	0.86	0.20	17.85	0.000***	2.358
Constant	-21.26	5.49	14.98	0.000***	0.000

-2Log likelihood = 70.318; Nagelkerke; R^2 = 0.800; χ^2 = 138.760; Hosmer Goodness-of-Model-fit
Source: Logit Model output of survey data, 2019

asset ownership of respondents positively and significantly influenced highland maize adoption at 5 per cent significance level. The result implied keeping influence of other variables constant, a unit change on asset ownership facilitated highland maize adoption by factor of 1,000.

This finding is in congruent with other studies which have reported farmers rarely had similar access to assets and market information (Hill and Vigneri, 2014) and asset ownership was positively related to knowledge and adoption of technology (Milkias, 2017).

Access to highland maize extension service

A model output result showed positive and significant relationship between access to highland maize extension service and adoption at $P < 0.01$. Hence, getting access to highland maize extension service facilitated adoption by factor of 6.33.

The finding is similar with Anik and Salam (2015); Awotide *et al.* (2016); Million and Belay (2004); Nguezet *et al.* (2011) who stated farmers with less access to extension service were hampered to adopt new technologies and agricultural input supplies. Hence, extension services influenced adoption positively.

Households' perceived risk aversion

In light of this, as it was hypothesized, risks brought negative influence on highland maize adoption which could be initiated by farmers' awareness ahead of events. It is likely due to disfavoring climate change or risk-taking that households hardly used technology for production. As indicated on the model output, risks on highland maize production had indirect or disfavoring significant influence to adopt varieties at less than 1 per cent significant level. The odd ratio/coefficient verified that if household heads relatively faced no perceived risk on highland maize production, keeping other variables constant, he would probably increase its adoption by 7.15 factors relatively than who perceived risks. This implies in absence of negative influence of risks on highland maize, probability of being adopter is higher than that of non-adopters.

The result agreed with findings that state insect and pest infestations were important biological factors restraining crop production and causes of food deficit Muche *et al.* (2014).

Conclusion

KAS study was aimed at assessing prevailing effect of knowledge, attitude and skill on adoption pattern of highland maize varieties in the study areas. The descriptive statistical results showed out of 15 proposed only four i.e. sex, age, membership to organization and asset ownership were observed having odds of insignificant values or relationship. Focus Group Discussions and Key informant discussions pointed out highland maize extension services and training were inadequate in the study area. Likewise, market facilitators, lack of producers' organizations and involvement of traders in business with fair price as collectors and inputs service providers were the major market constraints that farmers are facing in the study area. Besides, highland maize adoption has been being predominantly carried out by men household heads in the area. Since Knowledge was a gap, giving additional acquaintances needs sound means of interventions. Large numbers of non-adopter farmers have negative aspiration towards the variety adoption. The statistical attitude status of the household heads that had positive and significant relationship with the adoption implies status of farmers' attitude is directly proportional to highland maize adoption. Thus, further integrated action is needed to change and pull the aspiration towards the technology. As training has a superior multiplier effects, adoption seemed to have shortest marked effect on yield, food and feed security and income generation due to less involvement of resource poor farmers' at large. This showed that contributions and competencies of the majority poor households were being less considered and addressed in highland maize adoption.
- *Establishing highland maize farmers' organization and effective market linkage should be in place to institutionalize the variety in rural development and agricultural endeavors.*

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Maize Journal (October 2020) 9(2): 125-130

RESEARCH PAPER

Export performance and prospectus of maize (*Zea mays* L.) in India

M. L. Nithyashree · Ganapati Mukri · M. Balasubramanian · R. N. Gadag

Abstract: Maize is third most important cereals grown in India. Maize supports Indian economy, being one of the agricultural commodities that earn foreign exchanges. However, over a period, domestic consumption of maize is increasing in India, which demands more production and/ or import. In the present paper, opportunity of maize for foreign trade was discussed. The data on total cereals, which are under trade, were obtained from export-import database of DGCIS and UN COMTRADE. It was observed that, maize-seed, which is the primary input in maize cultivation, has better potential for export. The Revealed Comparative Advantage was more than one for maize-seed compared to maize-grain, indicates its global competitiveness for export over maize-grain. However, export of maize-seed should not be over looked as opportunity before meeting the domestic maize-seed demand of Indian farmers.

Keywords: Export performance · Maize-seed · Maize grain · Revealed comparative advantage

Introduction

Maize provides over 20 per cent of total calories alone in human diets in more than 21 countries and over 30 per cent in 12 countries that are home to more than 310 million people. Among the top maize producing countries, United States of America hold the first position with the yield of 11.86 tons/hectare, followed by the countries, *viz*., European Union, Ukraine, China, Argentina and India. India is one of the top 10 maize producers in the world, contributing 2-3 per cent of the total maize production worldwide. South-East Asia is considered as the largest market for Indian maize and it is exported to Indonesia, Malaysia and Vietnam (Upreti, 2020).

Indian agriculture has witnessed impressive progress in recent decades relating to production and diversification of crop on account of this the sector has become more remunerative with marked an increase in the output by 2.65 times during 2004-05 and 2011-12 (Chand *et al.*, 2015). Further, it provided an opportunity to capture the rising global demand especially in fresh and processed food of various kinds. A notable composition shift in world food trade i.e. the share of processed food exports in total world food exports increased from 44 per cent to 63 per cent. This trend was more apparent in the developing countries where the share of processed food exports in total world food exports tripled during the period 1980-2006 (Jongwanich, 2009). At this juncture, export and import performance in India have undergone significant changes with rise in export growth of 26.60 per cent in meat and meat products, 24-25 per cent in sugar and spices and 16.40 per cent in cereals during 2003-04 to 2012-13 (Sheeba, 2019; Suresh, 2016). However, the potential of agri-trade is still untapped and its share in total India's export is only 11.23 per cent and a meagre amount is contributed to the world trade in the agricultural commodities (i.e. 2.23% in 2019). The quantum of agricultural commodity like processed products have close link to cereal crop especially maize. Further, other relevant points include uniqueness of maize as seed and grain; usage as feed for livestock and poultry, and contribution of these to the processed food sector. From the top ten exporter of agricultural product in the world, India's trade surplus increased ten-fold during 1991-92 to 2013-14. However, subsequently exports fell by 22 per

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Received: / Accepted:

cent (with increased imports by 62 per cent) resulting in a significant decline of trade surplus to the tune of 70 per cent between, 2013-14 to 2016-17 and further reduced in 2018-19 (TPCT, 2018 and DGCIS, 2019). This calls for in-depth analysis of export potential of agri-trade at the commodity level of various products in general and of cereals in particular. In this paper, a case of maize and its contribution, performance and potential for India in the global market *vis-a-vis* other major cereal crops has been presented. Taking in to account various factors like global trend, demand of various country, efforts are made to understand the prospects for maize both seed and grain, with probable implication for various stakeholders.

Materials and methods

The study uses the secondary data from various sources relating to major cereals for global and national export values. For analysing trade performance of maize data on export, import, trade balance and current year data on total cereals were collected from Directorate General of Commercial Intelligence and Statistics (DGCIS). Time series data on maize export and import during 2001-2019 was taken from UN COMTRADE (www.comtrade.un.org). The data was analysed by using the analytical technique and trend growth by following semi-log growth model.

$$\ln Y = \alpha + \alpha t$$

where, Y is the variable under consideration (export/import) and t is the time in years. The growth rate was arrived by using the formula, r = {Antilog (β)-1}100.

Growth in maize export and import in India and world is obtained during 2001-2019 and also for the sub-periods 2001-2011 and 2012-2019.

Revealed Comparative Advantage (RCA) provides a general indication and approximation of a country's competitive export strengths. It was analysed from the formula,

$$RCA_{ci} = \frac{\frac{X_{ci}}{\sum_{j\epsilon p} X_{cj}}}{\frac{X_{wi}}{\sum_{j\epsilon p} X_{Xj}}}$$

Where,

P is the set of all products (with i∈P),

Xci is the country C's exports of product i,

Xwi is the worlds's exports of product i,

Σj∈PXcj is the country A's total exports (of all products j in P), and

Σj∈PXwj is the world's total exports (of all products j in P).

Country said to be competitive producer if it has RCA for a given product id more than 1 and it is inferred as exporter of that product relative to a country producing and exporting that good at or below the world average.

Results and discussion

Indian agricultural export performance is undergoing significant changes in the past decade due to fluctuating trade balance, particularly after 2013-14, which is associated with increasing import and decreasing export (Figure 1). Rising global demand in cereals provides the opportunity for the country to expand the trade (Geetha and Srivastava, 2018). To realise this enhancing production and yield level of maize is a pre-requisite, which could contribute in a big way. Maize production in India has doubled in the past decades (12.04 million tonnes in 2001-02 to 28.75 million tonnes in 2017-18) exhibiting the highest production growth in the cereals. Also, increase in the productivity (3065 kg/ha) and irrigated area under cultivation (26.73 per cent) will be expected to boom the maize production further (Singh *et al*., 2017). The export scenario of total cereals presented in Table 1 and it indicated that India contributed around 6.48 per cent to the total world cereal export and 29.44 per cent, 2.55 per cent and 0.40 per cent by rice, sorghum and maize respectively. Apart from this potential of maize and wheat can also be visualized from the proportion and relative quantum of total world's exported value i.e. 35,576.53 and 39,973.99 million US $ respectively. In India, rice is the most dominated cereal crop exports to the tune of 96.23 per cent followed by maize (2.04%) which stands India to be ranked 19th country in the list of major maize exporters. The four leadings export countries are USA, Brazil, Argentina and Ukraine with exported value 8013, 7421, 5966 and 5,193 million US $ respectively constituted around 75 per cent of the total maize export in the world in 2019 (Figure 2).

Trend and growth performance of maize trade and its value is captured in Figure 3 and Table 2. Maize export trend followed inverse "U" shape, wherein export value

Figure 1. Trade performance of agri-commodities in India

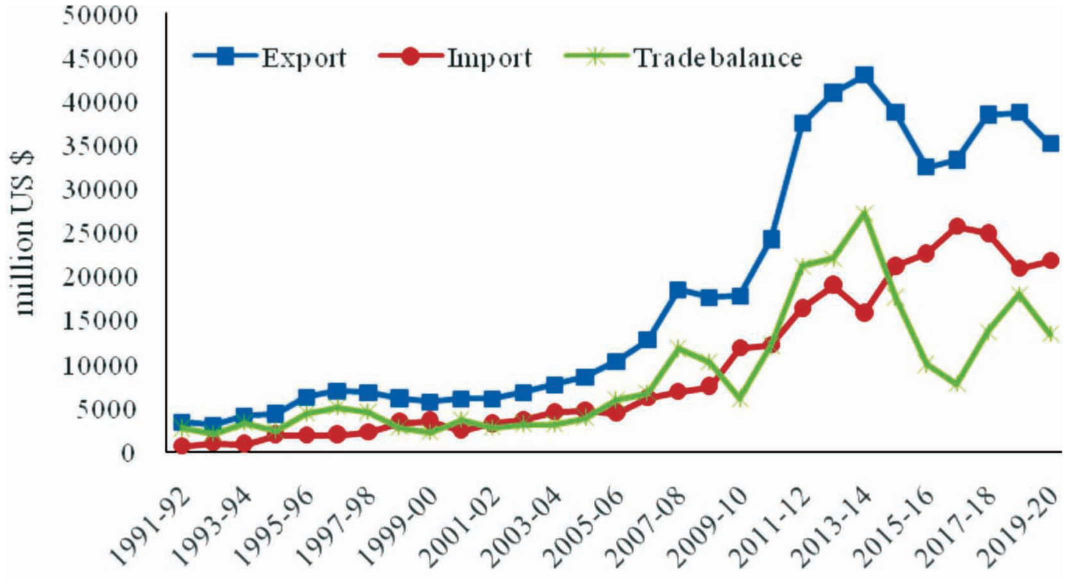

Table 1. Status of export across the cereal crops in India *vis-a-vis* world, 2019.

Crops	Value exported (million US$)		India's share in world trade (%)	Crop-wise share (%)
	World	India		
Rice	23,103	6,801	29.00	96.00
Maize	35,577	144	0.40	2.00
Wheat	39,974	54	0.14	0.76
Sorghum	843	22	3.00	0.30
Others	7,814	0.86	0.05	0.01
Total cereals	1,09,126	7,067	6.00	100.00

Source: Authors compilation using database DGCIS, UN COMTRADE

was rising steadily with the highest exported value of 1258.28 million us $ till 2013-14, at its peak. The trend subsequently was decreasing and reached to 143.85 million US $ in 2019. Contrary to the export performance, import of maize in India started to pick up in 2007 with the imported value of 2.32 million US $. Since then it followed an increasing trend and reached the maximum value as per the latest figures i.e. 76.45 million US $ in 2019. Export performance of maize in terms of growth in India followed same general pattern with that of the world trade, but different in magnitude. Overall growth of the world export in maize is recorded 8.37 per cent, the corresponding growth in India is comparatively high i.e. 13.08 per cent. Both world and Indian's export are more during 2001-11 and recorded negative growth from 2012 to 2019. Noteworthy to mention here is that magnitude of maize export growth in India was almost 5 times more than that of the world growth during 2001-11, similarly export reduced by 25 times less in India than that of the world export during 2012-2019. Similarly, world import growth recorded as 7.76 per cent, the corresponding growth in India is much higher i.e. 34.99 per cent. Nevertheless, the case of import is divergent, unlike the export, as per further elaborations and illustrations. World import reduced to -0.78 per cent in recent time, however while in India it continued to rise with the growth rate of 39.44 per cent. These general trends are indicators to say that India's trade balance in maize is decreasing gradually and there is a possible growth in the import in future.

Based on the purpose of use, maize is broadly classified as grain and seed, and their proportion to total maize export is plotted in the Figure 4. It is interesting to note the differences of trends for these two types of uses. There is a stable increase and decrease in maize-seed and maize-grain share in total maize export during the period 2001-2019. Further these patterns are more significant and apparent, particularly after 2015, which indicate increasing demand for the Indian maize seed industry. Growth performance and the trend pattern in the maize trade based

Figure 2. Major maize exporting countries in the world, 2019.

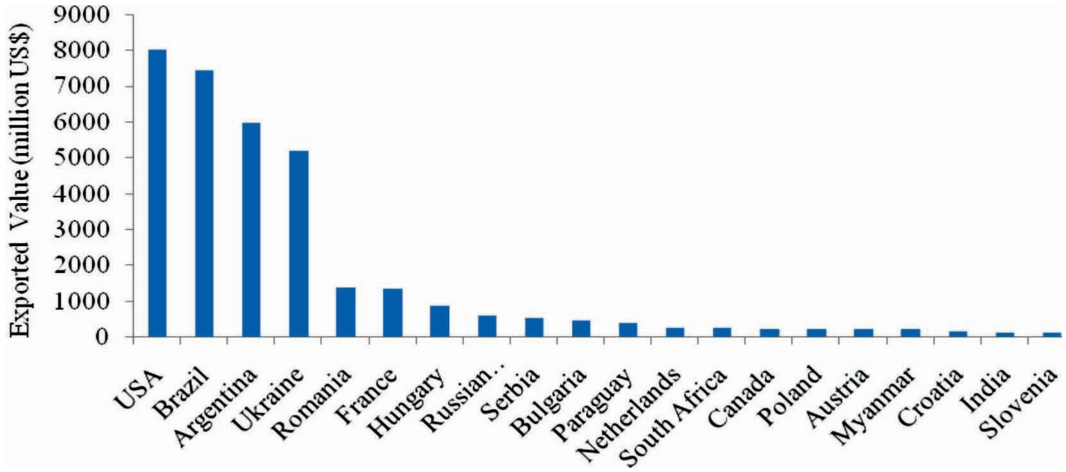

Figure 3. Trend in export and import of maize in India

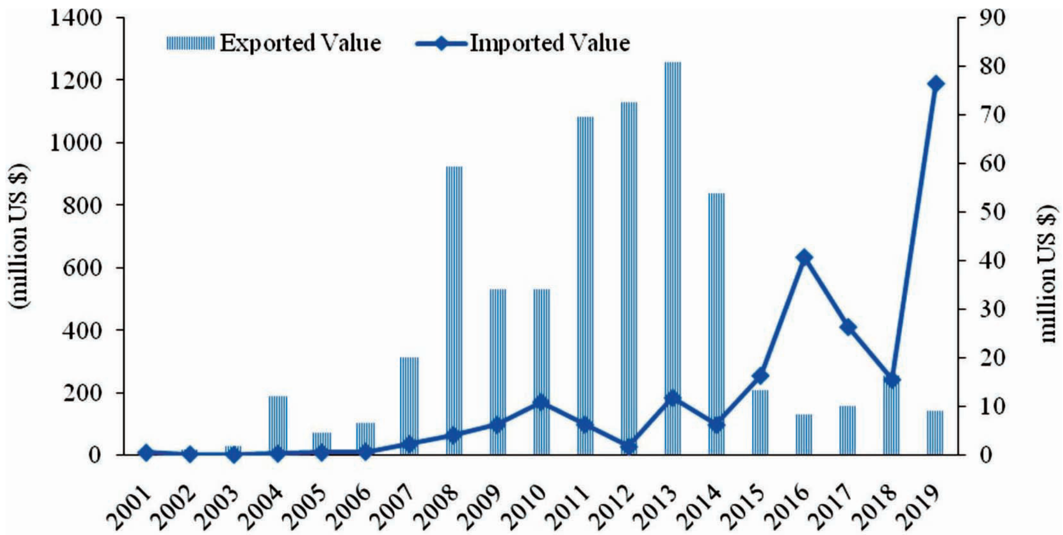

Table 2. Growth of maize exports and imports in India *vis-a-vis* world, 2001-2019 (%)

Export/Import	2001-2019	2001-2011	2012-2019
World export	8.37	12.90	-0.75[@]
India's export	13.08	57.56	-26.60[#]
World import	7.76	12.29	-0.78[@]
India's import	34.99	54.88	39.44

Note: growth rates are significant at 1 per cent level of significance unless otherwise mentioned:
@ Non-Significant, # 5 per cent level of Significance.
Source: Authors compilation using database UN COMTRADE

on the purpose of use clearly highlight the increasing demand in the domestic consumption for maize-grain. Currently maize use pattern shows that around 63 percent is consumed by poultry and cattle feed industry followed by starch (22%) and human consumption (9%) leading to the domestic consumption to the tune of 90 per cent (Anonymous, 2018). The poultry industry share in total meat production increased from 15 to 37 per cent during 1980 to 2005 and is expected to grow still faster due to the changing dietary patterns (Ali, 2007). In addition, there exists a niche global market for the maize-seed as well. It is evident from the Table 3 and 4 that countries like Malaysia, Germany, USA, France and Canada were the major importers with the tune of 10.30, 7.55, 6.75, 5.25 and 5.15 per cent respectively of the world total maize-seed import. Correspondingly, Japan, Korea, Mexico, Egypt and Vietnam were the major importer with the tune of 10.43, 6.98, 5.95, 5.72 and 5.71 per cent respectively of the world total maize-grain import. Currently India is exporting maize-seed to Bangladesh (34.4%), Myanmar (25.8%), Pakistan (21%), Nepal (9.3%) and Thailand (4.5%) and maize-grain majorly to Nepal (85.9%).

Based on Ricardian trade theory, RCA postulates the patterns of trade among countries which are governed by their relative differences in productivity and provide a general indication and approximation of a country's competitive export strengths. Thus, higher RCA for a

Table 3. Top ten importer of maize in the world, 2019 (%).

Country	Maize-seed	Country	Maize-grain
Malaysia	10.30	Japan	10.43
Germany	7.55	Korea	6.98
United States of America	6.75	Mexico	5.95
France	5.25	Egypt	5.72
Canada	5.15	Vietnam	5.71
Ukraine	4.04	Spain	5.52
Hungary	3.60	Iran	4.00
Russian Federation	3.42	Netherlands	3.93
Italy	3.26	Italy	3.45
Poland	3.09	Colombia	3.34
Total import (million US$)	3013.26	Total import (million US$)	33653.96

Source: Authors compilation using database UN COMTRADE

Table 4. Top ten import destinations of maize from India, 2019 (%).

Country	Maize-seed	Country	Maize-grain
Bangladesh	34.4	Nepal	85.9
Myanmar	25.8	Bhutan	3
Pakistan	21	Yemen	2.6
Nepal	9.3	Japan	2.4
Thailand	4.5	Saudi Arabia	1.8
Viet Nam	1.3	Oman	1
Philippines	0.9	Viet Nam	0.7
Tanzania	0.9	United Arab Emirates	0.7
Indonesia	0.4	Philippines	0.3
Iraq	0.3	Sri Lanka	0.3
Total export (million US$)	42.94	Total export (million US$)	100.9

Source: Authors compilation using database UN COMTRADE

commodity with a value of more than 1 implies that country has comparative advantage for that product. The trend in RCA for maize based on the purpose of use during 2001-2019 is provided in Table 5. The RCA for maize-seed ranged from 0.32 (2011) to 6.40 (2004) whereas corresponding values for maize-grain ranged from 0.15 (2001) to 2.99 (2008). The RCA in maize-seed from 2002 to 2008 was consistently more than one and reduced to less than one thereafter until 2017; interestingly it has

Table 5. Revealed comparative advantage of India's maize export

Year	Maize-seed	Maize-grain
2001	0.65	0.19
2002	1.17	0.15
2003	1.22	0.26
2004	6.40	1.39
2005	1.11	0.62
2006	1.04	0.76
2007	1.07	1.47
2008	2.94	2.99
2009	0.91	1.98
2010	0.57	1.65
2011	0.32	2.05
2012	0.33	2.16
2013	0.47	2.17
2014	0.52	1.64
2015	0.51	0.45
2016	0.64	0.24
2017	0.73	0.27
2018	1.26	0.38
2019	1.01	0.18

Source: Authors compilation using database UN COMTRADE

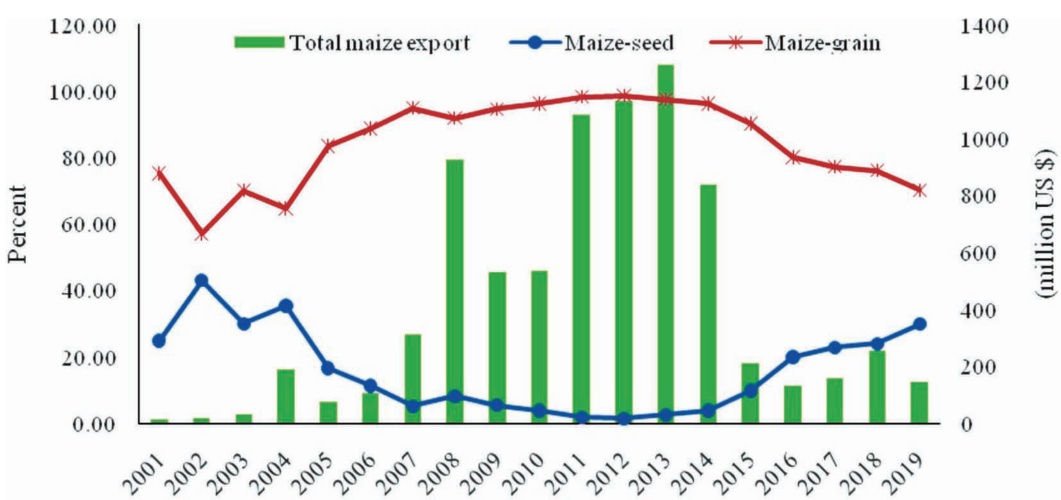

Figure 4. Trend in share (%) of maize export based on the purpose of use in India.

gained comparative advantage with the RCA value of 1.26 and 1.01 in 2018 and 2019, respectively. On the contrary, RCA for maize-grain was less than one during 2001-2006 (except in the year 2004). It gained comparative advantage during 2007-2014, but then lost it comparative advantage since 2015. It is indicated that in recent years maize-seed has become more competitive than maize-grain. Thus considering and fulfilling the domestic maize-seed demand, surplus can be targeted for niche market like Malaysia and other Asian countries.

Conclusion

Comparative analysis of trade and commodity parameters for cereals from Indian prospective revealed interesting insights. Maize as grain and seed during the last two decades and generalization trends has been important implications for various clients, researches and policy makers. Maize export performance indicated reduced trade balance over the period of time coupled with reduced export and increased import. There is a possible growth in the import in future particularly for grain purpose. On the other hand, there exists a niche global market for the maize-seed indicated by the rising export of maize-seed with existing competitive advantage. To sum up, the potential of maize is two-fold; increasing domestic consumption and rising demand for maize-seed in the global market. Policy favouring maize cultivation and seed production will not only help to capture the global market, it will also reduce the import consumption. The need for appropriate pro-active intervention is felt, which will otherwise affect trade balance in maize trade in particular and agri-trade in general.

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Maize Journal (October 2020) 9(2): 131-133

SHORT COMMUNICATION

Evaluation of seed treatment against Spotted stem borer *Chilo partellus* (Swinhoe) infesting maize

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Abstract: Field experiment was conducted to evaluate the efficacy of insecticides against stem borer *Chilo partellus* (Swinhoe) on maize. The insecticides *viz*., thiamethoxam 30 FS @ 6.0 ml, 8.0 ml and 10.0 ml/kg seed, imidacloprid 600 FS @ 4.0 ml, 6.0 ml and 8.0 ml/kg seed, chlorpyriphos 20 EC @ 5.0 ml/kg seed and fipronil 5 SC @ 6.0 ml/kg seed against *C. partellus* infesting maize under artificial infestation conditions was conducted during *kharif*, 2017 at Agronomy Farm, RCA, Udaipur. The observations were recorded at 30 days after artificial infestation in terms of leaf injury, number of dead hearts and damage plant by *C. partellus*. The results revealed that the thiamethoxam 30 FS @ 10.0 ml/kg seed was found best treatment in minimizing the *C. partellus* population with lowest LIR of 3.67, minimum no. of damaged plant (4.90), minimum dead hearts (4.10) and highest grain yield of 45.88 q/ha. The next effective treatment was thiamethoxam 30 FS @ 8.0 ml/kg seed with LIR (4.06), minimum no. of damaged plant (6.30), minimum dead hearts (5.20) and highest grain yield of 44.40 q/ha compare to other treatments. It was also found that phytotoxicity symptoms were not observed on maize plants in any treatment.

Keywords: *Chilo partellus* · Imidacloprid. LIR · Maize · Seed treatment · Thiamethoxam

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Received: 11 June 2020/ Accepted: 27 July 2020

Globally maize (*Zea mays* L.) is one of the most important cereal crops in the agriculture economy after wheat and rice. Maize is cultivated for various purposes including grain, fodder, green cobs, sweet corn and baby corn. It is the third most important cereal crop in India after Wheat and Rice. It is also known as “Queen of cereals”. In India maize is grown widely under extremely divergent agro-climatic conditions. The multiple pest complex of maize crop poses serious limitations in the maize production in different agro-climatic regions of India. As many as 250 species of insect pests attack maize in field and storage conditions (Mathur, 1991). Amongst, maize stem borer, *Chilo partellus* (Swinhoe) is the most serious one during *kharif* season causing 26.7-80.4 per cent yield losses in different agro-climatic regions of India (Panwar, 2005).

In India, *C. partellus* is one of the most serious insect pests of maize at the pre-harvest stage (Sarup *et al*., 1987). The larvae cut the growing point resulting in drying up of the central shoot and leads to formation of dead heart which on pulling comes out easily and plant vigor lost and reduction in grain yield. The loss due to *C. partellus* varied from 26.7 to 80.4 per cent in different agro-climatic regions of India (Chatterji *et al*., 1969). Several insecticidal recommendations have been made from time to time by various workers for the management of this pest. Keeping in view of the importance of maize crop and the economic losses caused by the *C. partellus* during *kharif* season, the present study aimed to evaluate the efficacy of different insecticides as seed treatment for its management.

The present experiment was carried out at the Agronomy farm, Rajasthan College of Agriculture, Udaipur, during *kharif*, 2017. Udaipur is located at 23.4^{o} N longitudes and 75°E latitude at an elevation of 579.5 MSL (Mean Sea Level) in the state of Rajasthan. The experiment was laid out in Randomized Block design (RBD) with nine treatments including one untreated control and each treatment was replicated three times. The insecticides were thiamethoxam 30 FS @ 6.0 ml, 8.0 ml and 10.0 ml/kg seed, imidacloprid 600 FS @ 4.0 ml, 6.0 ml and 8.0 ml/kg seed, chlorpyriphos 20 EC @ 5.0 ml/kg seed and fipronil 5 SC @ 6.0 ml/kg seed. The plot size was 4.5 m × 3.0 m with row to row and plant to plant spacing of 75 cm × 20 cm, respectively. The maize variety Pratap 3 was sown for the experiment. The observations on the efficacy of different insecticides against stem borer was recorded in terms of leaf injury rating (LIR), phytotoxicity symptoms, number of damaged plant and number of dead hearts per ten selected plants in each replication at 30 days after infestation and yield at harvest. The leaf injury rating from ten selected plants in each plot was scored based on 1-9 scale on 1-9 scale (Sarup *et al.*, 1978). The dead heart due to attack of stem borer were counted from three inner rows. Phytotoxicity symptoms like leaf injury, wilting, vein clearing, necrosis, epinasty and hyponasty on maize plants were observed by using 0 to 10 visual rating scale. Maize grain yield was obtained after crop harvest and expressed in quintal per ha. Data were subjected to statistical analysis by using ANOVA.

The data on leaf injury rating, number of damaged plants, number of dead hearts and yield is presented in Table 1. All the insecticides were significantly superior over untreated check at 30 days after infestation. The minimum leaf injury rating of 3.67 was recorded in thiamethoxam 30 FS @ 10 ml/kg of seed, followed by thiamethoxam 30 FS @ 8 ml/kg of seed with leaf injury rating of 4.06. The maximum leaf injury rating (7.13) was recorded in untreated control. All the insecticides were significantly superior over untreated check at 30 days after infestation. Among all the treatments, thiamethoxam 30 FS @ 10 ml/kg of seed was performed best with minimum no. of damaged plant (4.90) followed by thiamethoxam 30 FS @ 8 ml/kg of seed with 6.30 mean no. of damaged plant. The maximum number of damaged plants was reported in fipronil 5 SC (12.30) and untreated control (16.20). The mean number of dead hearts varied from 4.10 to 11.40 in different insecticidal treatments while it was 15.25 in control treatment. All the treatments were found significantly superior as compared to untreated control. The minimum dead hearts (4.10) was found with the treatment of with thiamethoxam 30 FS @ 10 ml/kg of seed followed by thiamethoxam 30 FS@ 8 ml/kg of seed (5.20). The highest dead heart (15.25) was recorded with untreated control, significantly higher than rest of the treatments. The data pertaining to grain yield reported that yield varied from 36.90 to 45.88 q/ha in different treatments. The highest grain yield of 45.88 q/ha was recorded in thiamethoxam 30 FS @ 10 ml/kg seed followed by thiamethoxam 30 FS @ 8 ml/kg seed (44.40 q/ha) compare to lowest yield in untreated control (36.90 q/ha). Phyto-toxicity symptoms *viz.*, leaf injury, wilting, stunting, necrosis, vein clearing, epinasty, hyponasty, etc.) were not observed on maize plants in any treatment

Table 1. Evaluation of seed treatment of different insecticides against *C. partellus* on maize

Treatment	Dose (ml/ kg seed)	Mean leaf injury rating at 30 DAI	Mean damaged plant at 30 DAI	Mean number of dead hearts at 30 DAI	Mean Yield (q/ha)
Thiamethoxam 30 FS	6	4.20	8.20	7.10	44.15
Thiamethoxam 30 FS	8	4.06	6.30	5.20	44.40
Thiamethoxam 30 FS	10	3.67	4.90	4.10	45.88
Imidacloprid 600 FS	4	4.67	11.10	9.95	42.68
Imidacloprid 600 FS	6	4.60	9.80	8.30	43.15
Imidacloprid 600 FS	8	4.13	7.30	6.20	44.37
Chlorpyriphos 20 EC	5	5.87	14.26	13.32	40.10
Fipronil 5 SC	6	5.20	12.30	11.40	40.82
Untreated Control	-	7.13	16.20	15.25	36.90
S.Em±	-	0.409	0.337	0.538	0.964
CD @ 5%	-	1.226	1.010	1.611	2.889

DAI: days after infestation

Table 2. Phyto-toxicity of treatments

T. No.	Treatment	Dose (ml/kg Seed)	Phytotoxicity parameters observed at 30 days after seed treatment				
			Leaf injury on tips/surface	Wilting & Stunting	Vein clearing	Necrosis	Epinasty/ Hyponasty
T1	Thiamethoxam 30 FS	6	0	0	0	0	0
T2	Thiamethoxam 30 FS	8	0	0	0	0	0
T3	Thiamethoxam 30 FS	10	0	0	0	0	0
T4	Imidacloprid 600 FS	4	0	0	0	0	0
T5	Imidacloprid 600 FS	6	0	0	0	0	0
T6	Imidacloprid 600 FS	8	0	0	0	0	0
T7	Chlorpyriphos 20 EC	5	0	0	0	0	0
T8	Fipronil 5 SC	6	0	0	0	0	0
T9	Untreated Control	-					
	CD @ 5%	NS	NS	NS	NS	NS	

(Table 2). The present results are in conformity with the study of Anuradha (2012) who found significant result of different doses of thiamethoxam 30 FS for controlling maize stem borers, *C. partellus* and *Sesamia inferens* Walker. Among the doses tested, higher dose of thiamethoxam 30 FS (8ml/kg seed) proved superior resulting in 0.38 per cent dead hearts with higher grain yield of 5.4 t/ha. They also concluded that phytotoxic effects like necrosis, vein clearing, epinasty etc. were not observed even at the highest dose in thiamethoxam 30 FS 16 ml/kg seed. In the present experiment the results of lower efficacy of imidacloprid as seed treatment against stem borer in maize are in accordance with Kumar and Mihm (1996) and Pons and Albajes (2002).

From the present study it is concluded that the maize stem borer infestation can be minimized by a single dose of seed treatment with thiamethoxam 30 FS @ 10 ml/kg of seed.

Acknowledgement

The authors thank to the Head, Department of Entomology and Director Research, Maharana Pratap University of Agriculture and Technology, Udaipur for providing the necessary facilities to conduct the experiment.

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ACKNOWLEDGEMENT

The Maize Technologists Association of India thankfully acknowledges the contribution of following reviewers for critically revieweing the manuscripts submitted to Maize Journal during 2020.

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An International Journal of Maize Research and Related Industries

Volume 9, Number (2), October 2020

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