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Growth of Maize Ecosystem in India and Karnataka Vis-a-Vis Associated Risk in Production : An Economic Insight

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Abstract

Maize is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because of its highest genetic yield potential among the cereals. In addition to staple food for human being and quality feed for animals, maize serves as a basic raw material as an ingredient to thousands of industrial products. Growing area under maize and increasing MSP for maize will reflect importance of maize and its multiple benefits. In this study, the growth in area, production and productivity of maize in India and Karnataka and risks associated with maize production in Karnataka were analyzed. The primary data pertaining to study was collected from major maize growing districts of Karnataka and secondary data on area, production and productivity of India and Karnataka was collected from Indiastat.com and the Directorate of Economics and Statistics, Government of Karnataka. Significant growth rates in maize area (1.12), production (3.51) and productivity (2.36) were recorded in India as a whole for the period 1970-2019. The share of maize in total food grain production has increased from 3.40 per cent in 1950-51 to 9.98 per cent in 2020-21. The cumulative annual growth rate of maize area (4.80), production (6.08) and productivity (1.52) has showed positive significant scores in Karnataka. Water scarcity, non-availability of inputs at right time and unstable yield were major risks associated with maize production before the infestation of fall armyworm, but pest and disease, unwanted moisture in the field and low quality of fodder were major risks associated with maize production after the introduction of fall armyworm in the study area.

Keywords : Area, Production & productivity of maize, Growth rate, Production risk, Fall armyworm

Maize (*Zea mays* L) being one of the versatile emerging crop with wider adaptability under different agro-climatic environmental conditions. Because of its high level of genetic yield potential among all cereals, maize is known as 'Queen of Cereal's globally (Manjanagouda and Kalyanamurthy, 2018). Maize is a vital crop for millions of people in the form of food, fodder, feed and industrial raw material. Globally, around 1147.7 million metric tonnes of maize is produced from 193.7 million hectare with an average yield of 5.75 tonnes per hectare in 170 countries (Meena and Nirupma, 2021) with a diverse range of soil, climate, biodiversity and management approaches, accounting for 36 per cent of world grain production.

Maize is widely used for a many purposes around the world, including feed 61 per cent, food 17 per cent and industry 22 per cent. China leads the globe in maize area under cultivation, followed by the United States, which together account for 39 per cent of global maize area. Since 2005, India has ranked fourth in terms of area and seventh in terms of production, accounting for about 4 per cent of global maize area and 2 per cent of overall production. In India, the maize acreage grew to 9.2 million hectares in

2018-19 (Meena and Nirupma, 2021). During 1950-51 India produced 1.73 million tonnes maize, which has increased to 27.8 million tonnes by 2018-19, recording close to 16 times increase in production. During this period, average productivity surged by 5.42 times, from 547 kg/ha to 2965 kg/ha, meanwhile the area under maize cultivation nearly tripled to 9.2 million hectares. The United States produces 34 per cent of the world's maize, followed by China 22per cent. Since 1961, India has ranked top ten among the maize producers in the world, with an annual production of roughly 28 million tonnes. In India, maize productivity is slightly higher than 3 t/ha, which is slightly higher than half of the global average (5.6 t/ha).

After rice and wheat, maize is India's third most significant food crop, having the largest output potential among cereals. Since mid-1980s there is a distinct shift in maize cultivation, when larger area under maize shifted to peninsular India. Currently peninsular India represents over 40 per cent of maize area and 50 per cent total maize production. Karnataka (1.3 mha), Madhya Pradesh (1.3 mha), Maharashtra (1.0 mha), Telangana and Andhra Pradesh (0.9 mha), Rajasthan (0.8 mha) are the principal maize growing states of the country.

Currently 47 per cent of maize produced in India is consumed in feed industry, while 13 per cent as animal feed. Starch industry consumes around 14 per cent of maize and other industries use maize as a primary raw material, including starch, oil, protein, alcoholic drinks, food sweeteners, pharmaceutical, cosmetic, film, textile, gum, package and paper industries *etc.* Over the decade use of maize as direct food has reduced considerably, now pegs at around 13 per cent. However, there is an increasing trend to use maize as processed food, which contributes to around 7 per cent of annual maize consumption in the country. Use of specialty corns, *viz.,* sweet corn, baby corn and popcorn is a recent dimension where maize cultivation is getting integrated with rural entrepreneurship and agro-business. With all of these benefits, maize is the best crop for accomplishing the government's goal of doubling farmer's income.

In Karnataka, maize is grown over an area of approximately 1.3 mha producing 26.4 lakh tonnes. Particularly in Central part of Karnataka *viz.,* Shimoga (0.585 lakh ha), Davangere (1.74 lakh ha) and Chitradurga (0.67 lakh ha) districts. In the past ten years maize has registered tremendous increase in area compared to any other crops and has replaced other rainfed area crops in the state like potato, tobacco, cotton, groundnut, ragi and sorghum.

Due to drastic expansion of area under maize and its increased cultivation, risk components have also increased. Since the majority of maize is rainfall dependent and the production is unstable due to lack of irrigation facilities is one among the major limiting factors and along with other production risks already present in the production of maize, the fall armyworm's introduction in 2018 started having a significant influence on maize output.

Material and Methods

Karnataka is the major maize producing state in the country and has registered a positive significant growth rates in last two decades overtaking other states and becoming number one in terms of area and production. Based on area, production, productivity and fall armyworm incidence on maize, four major maize growing districts *viz.,* Davanagere, Haveri, Hassan and Chikkaballapur were selected for the study. The ultimate sample of farmers numbering 50 from each district was chosen randomly from the cluster of villages to form overall sample size of 200 maize farmers.

A structured schedule was prepared and pretested before it was administered to the respondent farmers. The schedule covered general information on maize farmers, their asset position and details of maize crop production in terms of input usage, costs, income, production risk associated and damage caused by fall armyworm *etc.* For assessing the production risk associated, yield loss. Secondary data on area, production and productivity of India as a whole were collected from Indiastat.com for the period 1970-2019 and for Karnataka State Secondary data on area, production and productivity and rainfall as a whole

The Mysore Journal of Agricultural Sciences

were collected from Directorate of Economics and Statistics, Govt. of Karnataka, Bengaluru for the period 2000-2020.

Analytical Tools Used

Exponential Growth Model

Growth rates for area, production and productivity of maize in India and Karnataka were computed for a period of 50 years from 1970 to 2019 and 2000 to 2020 for India and Karnataka, respectively. Several functional forms were used to estimate the growth rates of the selected economic variables. Finally, exponential growth model was selected for the analysis and the model is of the following form.

$Y = ab^t e$ ..... (1)

Where

Y = Dependent variable for which the growth rate is estimated (area, production, productivity of maize).

a = Intercept

b = Regression coefficient

t = Time variable (1970 to 2019) for area, production, productivity for India) (2000to 2020 for Karnataka)

e = Error term

The compound growth rate was obtained from the logarithmic form of the equation (1) as below.

$\ln Y = \ln a + t \ln b$

The per cent compound growth rate (g) was derived using the relationship

g= (Anti ln of b - 1) X 100

Instability Analysis

The coefficient of variation was used as a measure to study the variability in area, production, productivity and input use in rainfed maize in Karnataka. The coefficient of variation (CV) or index of instability was computed using the following formula

$$CV = \frac{\text{Standard Deviation}}{\text{Mean}} \text{ X } 100 \ldots\ldots (2)$$

Linear trend was fitted to the original time series data, for a period of 50 years from 1970 to 2019 for India and 2000 to 2020 for Karnataka. The trend coefficients were tested for their significance. Whenever the trend of series was found to be significant, the variation around the trend rather than the variation around mean was used as an index of instability. The formula suggested used to compute the degree of variation around the trend, mean, coefficient of variation was multiplied by the square root of the difference between the unity and coefficient of multiple determination (R2) in the cases where R2 was significant to obtain the Instability Index.

$$\text{Instability Index} = \frac{\text{Standard Deviation}}{\text{Mean}} \text{ X } 100 \text{ X } \sqrt{(1- R^2)} \ldots\ldots (3)$$

R^2 = Coefficient of Determination

A high degree of instability index signifies violent variations.

Garret's Ranking Technique

An attempt was made to recognize the problems faced by the growers in the cultivation of Maize. The identified problems of growers in the cultivation of maize were ranked by making use of Garrett's Ranking Technique. The technique was used to rank the preference mentioned by the respondents on different factors and aspects of the cultivation process. It is used to find the most significant factor which had influenced the respondent in their practices. Founded on the Garret's Ranking technique, the study had the respondents rank different problems and outcome based on their impact thereby converting into score value and rank with the help of the following formula:

$$\text{Percent position} = \frac{100 (\text{Rij} - 0.5)}{\text{Rij}}$$

Where,

Rij = Rank given for the i^{th} variable by j^{th} respondents

Nj = Number of variable ranked by j^{th} respondents

With the help of Garrett's table, the per cent position estimated is converted into scores by referring to the table. Then for each factor, the scores of each individual were added and then total value of scores and mean values of score was calculated. The factors having highest mean value was considered to be the most important factor.

Results and Discussion

Growth Rates in Area, Production, Productivity of Maize

Compound growth rates were computed to comprehend the trends in area planted, production and productivity in maize cultivation. The study period was from 1970 to 2019 and (sub divided into Period-I (1970-1979), Period-II (1980-1989), Period-III (1990-1999), Period-IV (2000-2009) and Period-V (2010-2019)) and 2000 to 2020 for India and Karnataka, respectively and the exponential growth function was employed to find out the growth rates during the above mentioned period.

The results of estimated growth rates are presented in Tables 1 and 3. Negative growth was observed in area (-0.13), production (-0.63) and productivity (-0.50) of maize during Period-I (1970-1979) and found statistically non-significant, because the major traditional maize growing areas like Bihar, Madhya Pradesh, Uttar Pradesh and Rajasthan most farmers use to grow local maize varieties during rainy season, low use of input levels far below than recommended level and seed replacement is very low (Joshi, *et al*., 2005). During Period-II (1980-1989) again negative growth was observed in area but production and productivity has shown a positive growth rate but found statistically non-significant and medium instability in production was observed during the

Table 1

Decade wise temporal variation of area, production and productivity of maize in India

Particulars	Area ('000 ha)	Production ('000 t)	Productivity (Kg/ha)
Period-I (1970-1979)			
Mean	5843	6172.9	1055.6
CAGR	-0.13	-0.63	-0.5
p value	0.65	0.66	0.7
CV %	2.34	12.08	11.09
Instability Index	2.45	12.65	11.64
Period-II (1980-1989)			
Mean	5839.3	7451.2	1274.5
CAGR	-0.19	1.87	2.06
p value	0.5	0.3	0.21
CV %	2.28	15.5	14.5
Instability Index	2.34	15.32	13.85
Period –III (1990-1999)			
Mean	6104.3	9928.6	1623.6
CAGR	0.95 ***	3.28 ***	2.32 ***
p value	0.0003	0.001	0.01
CV %	3.14	11.26	8.78
Instability Index	1.38	6.2	5.92

Table 1 Continued.....

Particulars	Area ('000 ha)	Production ('000 t)	Productivity (Kg/ha)
Period-IV (2000-2009)			
Mean	7463.7	15072.3	2007.4
CAGR	2.93 ***	5.29 ***	2.28 **
p value	5E-06	0.001	0.05
CV %	8.91	18.32	11
Instability Index	2.38	9.99	9.01
Period-V (2010-2019)			
Mean	9067.8	24787.6	2728.4
CAGR	1.06 ***	3.47 ***	2.39 ***
p value	0.01	0.0002	0.001
CV %	4.11	11.4	8.4
Instability Index	2.75	4.82	4.4

same period. Since, majority of maize area in India is rainfed the production is dependent on good rainfall whenever there is a of lack of rainfall during cropping period leads to instability in production the variance of production of maize was mainly due to factor other than area and productivity (Kiran, *et al*.., 2018) Whereas during Period-III (1990-1999) there was a positive compound annual growth rate of area (0.95), production (3.28) and productivity (2.32), which was statistically significant at one per cent level. This is mainly due to expansion of area and use of hybrid seeds resulting in higher yields in non-traditional maize growing area like Karnataka and Andhra Pradesh. Farmers in these areas grow maize as a commercial crop and there was close linkage between maize production and the poultry sector (Joshi, *et al*., 2005). The average productivity during the period stood at 1623.6 kg/ha which is 350 kg higher compared to previous period and the coefficient of variation was 8.68 per cent which was lower compared to 14.50 per cent in the previous period.

In the Period-IV (2000-2009) significant growth rates were observed in area, production and productivity of maize however, along with increase in growth rates the instability index was also increased compared to previous period. Further, during Period-V (2010-2019) the positive and significant trend in area, production and productivity of maize was observed. Also during the same period the instability index indicated improved values in production (4.82) and productivity (4.40) compared to previous period. The average productivity has increased considerably from 2007.40 kg/ha in Period-IV (2000-2009) to 2728.40 kg/ha in Period V (2010-2019) the area expansion is mainly because depletion of groundwater, the farmers were shifting from unprofitable cultivation of rice to maize because the maize crop can be grown using three to four irrigation and wider adoption of high yielding varieties lead increase in productivity as well as production (Yadav *et al*., 2016).

Growth of 1.12 per cent in area, 3.51 per cent in production and 2.36 per cent in production of maize in India was observed for overall period from 1970 to 2019 and was statistically significant at one per cent level (Table 2). Mean productivity of maize during the period in India stood at 1737.9 kg/ha, whereas medium instability (15.70) was observed for the period 1970 to 2019 in production of maize in India.

Significant positive growth was observed in area production and productivity of maize in Karnataka for the period 2000-2020 (Table 3). The instability in production of maize in Karnataka was 22.26 followed by 17.61 in productivity and 11.73 in area the mean productivity for the period was 2941 kg/ha. A study by Joshi *et al*. (2005) observed that the positive

TABLE 2

Temporal variation of area, production and productivity of maize in India

Particulars	Area (lakh ha)	Production (lakh t)	Productivity (Kg/ha)
Period – (1970-2019)			
Mean	68.64	126.83	1737.9
CAGR%	1.12***	3.51***	2.36***
p value	0.00000006	0.0000002	0.00000001
CV%	19.16	55.92	35.83
Instability index	8.44	15.70	9.97

TABLE 3

Decadal temporal variation of area, production and productivity of maize in Karnataka

Particulars	Area (lakh ha)	Production (lakh t)	Productivity (Kg/ha)
Period – (2000-2020)			
Mean	11.38	33.37	2941.00
CAGR%	4.80***	6.08***	1.52**
p value	0.00000001	0.000002	0.03
CV%	28.15	39.56	19.63
Instability	11.73	22.26	17.61

growth of maize in Karnataka is attributed to adoption of modern varieties, strong seed sector, timely rainfall or proper irrigation and strong demand for maize from the rapidly growing poultry sector. Singha and Naphde (2012) reported that lack of irrigation was one of the key reasons responsible for many farmers switched from rice to maize cultivation.

During 1950-51, the per cent share of maize area to total food grain area in India was at 3.25 per cent and 3.40 per cent in production, whereas during 1990-91 the percent share of maize in total food grain has increased to 4.20 per cent in area and 5.08 per cent in production. Further in 2020-21, the per cent share of maize area to total food grain area in India was increased to 7.62 per cent which was more than double and production 9.98 per cent which was three times higher compared to the year 1950-51 (Table 4). The rise in the per cent share of area and production of maize to total food grain in India is driven by the area expansion as well as yield improvement by adoption of high yielding varieties, hybrids with relatively high use of inputsand strong demand driven bypoultry sector for feed followed by multiplicity uses of maize and implementation of government of India sponsored 'Integrated scheme of oilseeds, pulses, oil palm and maize' (ISOPOM) (Ranjit Kumar *et al*., 2014). As per Indian institute of maize research 47 per cent of maize is utilized for poultry feed and the remaining produce is utilized for a variety of purposes, comprising 13 per cent for food and livestock feed, 12 per cent for industrial usage, 14 per cent for the starch industry, 7 per cent for processed foods and 6 per cent for export and other uses.

TABLE 4

Decadal trend in percent share of maize to total food grain production in India

Year	Particulars	Total food grainIndia	%Share of maize
1950-51	Area	973.21	3.25
	Production	508.30	3.40
1990-91	Area	1404.28	4.20
	Production	1763.90	5.08
2000-01	Area	1210.48	5.46
	Production	1968.10	6.11
2010-11	Area	1266.71	6.75
	Production	2444.90	8.89
2020-21	Area	1297.95	7.62
	Production	3107.40	9.98

Sources of Production Risk Associated with Maize Production

The sources and extent of production risk faced by sample farmers was assessed by Garret's ranking technique which is presented in Table 5. Results revealed that before introduction of Fall armyworm the major problem in production of maize among sample farmers was drought/scarcity of water/extreme heat with an average score of 136.67 followed by unstable yield (120.25), availability of inputs (119.17), labour scarcity (116.87) and pest and diseases (116.02)

TABLE 5
Sources of production risk associated with maize production

Sources of Production risk	Before introduction of Fall Armyworm (n=200)		After Introduction of Fall Armyworm (n=200)	
	Average score	Rank	Average score	Rank
Drought/ water scarcity /extreme heat	136.67	1	126.62	2
Unstable yield	120.25	2	118.91	3
Availability of inputs (Seeds, Fertilizers, Pesticides etc) at right time and quality	117.58	3	116.45	5
Pests and diseases	117.34	4	143.47	1
Labour scarcity	116.87	5	117.28	4
weed infestation	115.66	6	113.85	8
Credit availability at low interest rate	112.96	7	110.89	9
Information access on maize production methods	109.36	8	110.21	10
Low quality of Fodder/Straw	107.91	9	114.88	7
Floods/unwanted moisture in the field	107.79	10	115.14	6

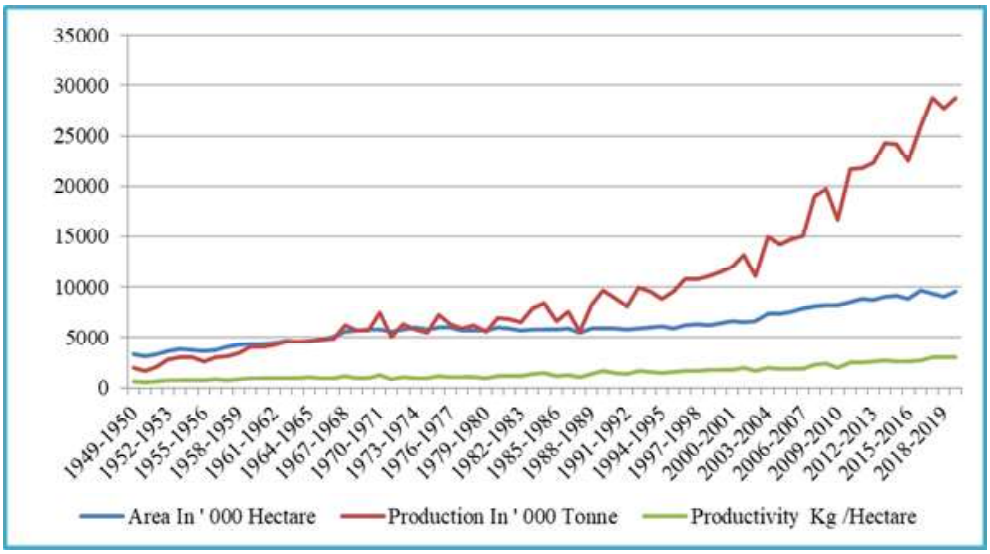

Fig. 1 : Trends in area, production and productivity of maize in India

were the major production risk faced by maize farmers in the study area. Weed infestation and credit availability was also felt as production risk by farmers with average score of 115.66 and 112.96, respectively. The least production risk in maize was associated with floods/unwanted moisture in the field with an average score of 104.64. The situation was changed after introduction of fall army worm in production of maize with major production problem being faced by farmers was pest and diseases with an average score of 145.98 among 200 sample farmers. Second major production risk as opined by farmers was drought/scarcity of water/extreme heat with average score of 124.35 followed by unstable yield (119.81), labour scarcity (117.28), availability of inputs (116.45). The least production risk in maize faced by sample farmers was

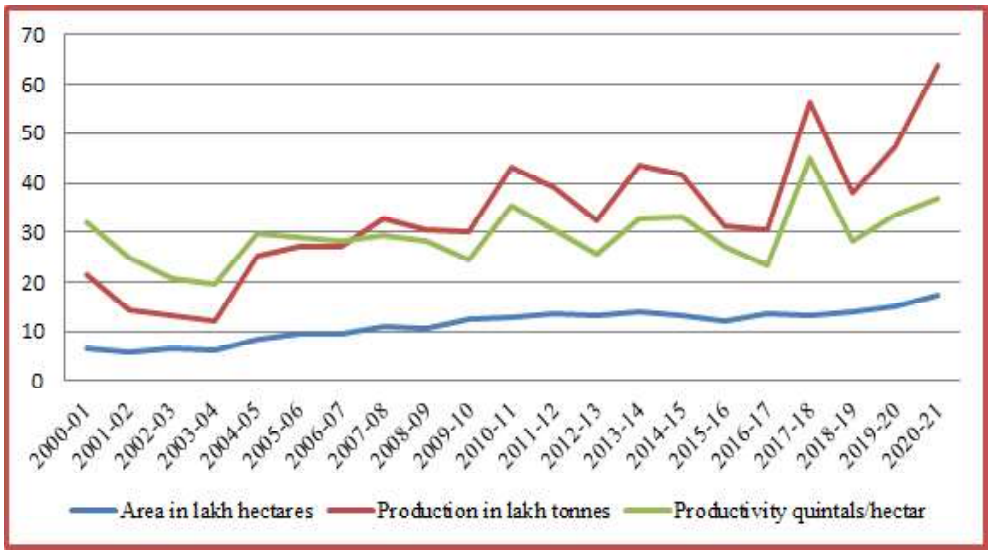

Fig. 2. Trends in area, production and productivity of maize in Karnataka
Decadal trend in percent share of maize to total food grain production in India

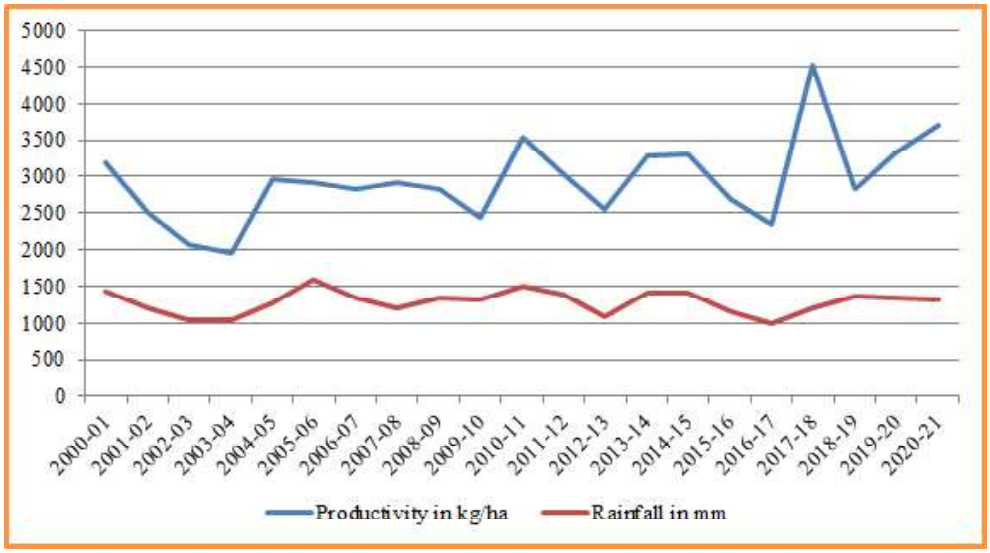

Fig. 3. Trends in rainfall and productivity of maize in Karnataka

information access to maize production methods with an average score of 110.21.

Drought was the major production risk faced by farmers before introduction of fall army worm in maize indicating importance of rainfall as it is apparent from the Fig. 1 that the productivity of maize is in synchronizing trend with the rainfall pattern of Karnataka shows the high dependency of maize production to rainfall hence, farmers opinion regarding same is correct with regard to drought and unstable yield. Availability of inputs at right time was also a major problem faced by farmers as this leads to low input use and low yield as opined by the farmers. Labour scarcity was given fourth rank in the production risks faced by maize farmers, due to availability of jobs in other sectors with higher wage rates labour problem is faced by all farmers in rural areas irrespective of crops. In general, it was considered that, maize is less risky crop as pest and

disease incidents are minimal but the introduction of fall armyworm in 2018 has changed the scenario with major problem being pest and diseases in the production of maize among sample farmers. Fall armyworm is causing devastating yield losses ranging from 22 to 67 per cent in Africa since its introduction in 2016 (Balla *et al*., 2019) and involves high management cost. Results are in line with the study conducted by Kathy *et al*. (2021) wherein they reported that they spent US$600 million in 2009 for controlling FAW. The average management cost of fall army worm was estimated to be $40/ha.

During past three decades maize production in India and Karnataka has increased significantly adding new regions and seasons with growing demand from the poultry, animal feed, starch and ethanol industries facilitated by government policies and adoption of single cross hybrids and high yielding varieties and switching from other crops to maize due to its high yield potential and low water requirement and having multiple uses has made the crop special from other cereals. Due to drastic expansion of area under maize and its increased cultivation, risk components have also increased. Since the majority of Indian maize is rainfall dependent and the production is unstable due to lack of irrigation facilities this is one among the major limiting factors and the incidence of fall armyworm started making serious impact on maize output further, reducing the national average yield of maize to less than 3.1 tonnes per hectare which is low as compared to other Asian countries This. calls for change in strategic approach and attention for planning and devising adaptation and mitigation strategies for future pest management programmes like framing stringent policies for control of invasive pest and diseases into country for sustainable production.

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