Assessment Of Key Kharif Season Maize Production Constraints In East Champaran District, India

Hillary M. O. Otieno

Abstract— This research aimed at assessing the current situation and challenges affecting the production of Kharif maize in East Champaran District. The research utilized focus group discussions and thorough literature review in assessing the production conditions and drawing recommendations. From the research, Kharif maize production is challenged by poor weed management that leaves the crop vulnerable to competitions for growth factors. Increasing drought frequencies and intensities were also noted to affect production. Waterlogging, due to relatively flat topography, was found to cause 60-80% maize yield loss when it occurs during critical growth periods. Pre-planting application, 1-2 weeks before planting, of readily soluble fertilizers such as DAP, urea, and MOP exposed the nutrients to early leaching before plants could establish proper roots. The losses were found to be aggravated by the broadcasting method of fertilizer application commonly practiced by the farmers in the region. Incidences of stalk borers were reported and could cause up to 95% of field yield loss if not controlled. Grain borer infestations at the stores could cause 10-25% of grain loss. High incidences of aflatoxin infection were also recorded. These challenges could be managed through prioritized research on key areas like drought, fertilizer use, pests and aflatoxin management) and improved agricultural extension services that offer training and dissemination of already available technologies and agronomic practices.

Index Terms— Conservation agriculture, drought impact, Kharif maize production, maize stalk borer, soil infertility, weed infestation.

———————————— ◆ ————————————

1. INTRODUCTION

Maize (Zea mays, L.) is the third most important food crop after rice and wheat with a production of about 28.72 million tons in 2017 in India (Faostat, 2019). The crop is traditionally produced in Madhya Pradesh, Utter Pradesh, Chhattisgarh, Jharkhand, and Bihar States which account for about 50% of the total national maize production (Figure 1) (Joshi et. al., 2005). Nationally, the crop contributes about 9% of the national food basket and generates about 100 billion to the agricultural GDP (Parihar et al., 2011). This is due to the important roles maize plays in the manufacturing and processing industries: 55% of total production is consumed as livestock and poultry feeds while only 25% for human consumption and about 11% for other industrial purposes (Kumari Meena & Singh, 2015).

Bihar State is one of the most important traditional maize producing regions in the country with about 712,000 hectares of land under cultivation and producing about 2,820,000 tons (Kumar and Singh, 2017). The average maize yields are higher at Bihar State (about 4 t/ha) compared to the national level (3.1/ha) (Kumar et. al., 2005; Faostat, 2019). This yield difference is majorly due to the higher yields realized under Rabi season (running from October to March). Otherwise, during the Kharif season (running from May/June to September), farmers get on average 2.4 t/ha (Kumar, Srinivas and Sivaramane, 2013).

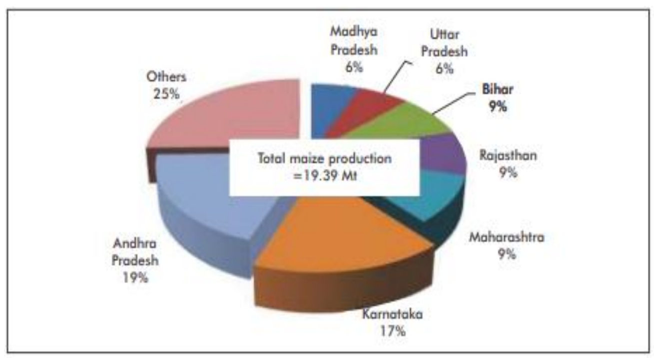

Figure 1: Major maize producing states in India. Source: Kumar, Srinivas, and Sivaramane, 2013

East Champaran District is among the main maize producers in Bihar State with a yield range of 2-4 t/ha according to Economic Survey carried out between 2010 and 2011 in Bihar (Table 1) (Government of India, 2013). Like other Districts, East Champaran has Rabi and Kharif seasons with extensive maize production occurring in the Rabi due to the absence of floods, and waterlogging conditions, low prevalence of pests, and disease (Kumar, Srinivas and Sivaramane, 2013).

Among other districts (Figure 2), East Champaran has shown declining maize production trend in recent years that could be attributed to climatic, biotic, edaphic and socio-economic related challenges.

• *Hillary M. O. Otieno, Department of Plant Science and Crop Protection, University of Nairobi, Nairobi, Kenya*
E-mail: hillarymomondi@yahoo.com

Table 1: Classification of maize producing districts based on yield category in Bihar State. These districts contribute more than 1% of the maize area in Bihar State. Source: Government of India, 2013.

Yield category	Districts	% share of total maize acreage
High maize productivity districts with grain yield more than 4 t/ha.	Samastipur, Saharsa, Supaul, and Araria	20.0%
Medium maize productivity districts with grain yield ranging 2-4 t/ha	Nalanda, Siwan, Gopalgani, West Champaran, East Champaran, Muzaffarpur, Vaishali, Darbhanga, Begusarai, Khagaria, Bhagalpur, Banka, Madhepura, Purnea and Katihar	68.6%
Low maize productivity districts with grain yield below 2 t/ha	Patna, Saran, and Munger	6.4%

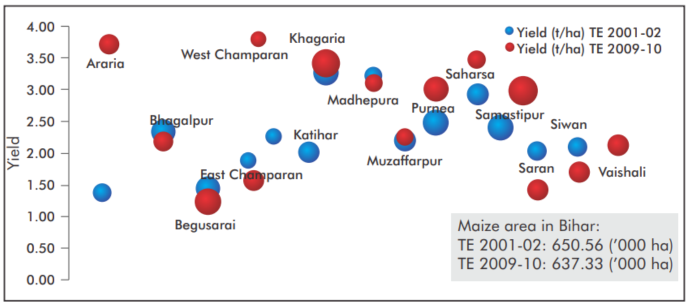

Figure 2: Changes in the area planted with maize area and the yields among major growing districts of Bihar State. Source: Kumar, Srinivas, and Sivaramane, 2013.

The above challenges have not been adequately assessed using both primary and secondary data in East Champaran District. This is because most research has since been focused on looking at constraints affecting maize production under Rabi season (as main seasons) with less attention given to Kharif season. Therefore, there is a need to have a region-specific assessment of these challenges for better research and management recommendations. This research therefore aimed at assessing the situation of maize Kharif maize and providing potential mitigation strategies available for improving yields in the East Champaran District.

2. Materials and Methods

This research focused on two sites, Harsidhi and Kalyanpur villages, located in East Champaran District, Bihar State. These two villages are among the top maize producers in the districts. East Champaran District is characterized by drought and floods that significantly impact on crops. Soils of the area are taxonomically classified into three orders; Alfisols, Inceptisols, and Entisols (Sattar et al., 2013). The area has hot summer with a temperature range of 35-46 0C and severe winter with a temperature range of 4-5 0C. The main rainfall in the region is received through South West Monsoon that occurs between the month of June and September. The average annual rainfall received in the region is about 1241.6 mm (IEED, 2018).

This research combined both primary and secondary data in the assessment. The primary data were collected during the focus group discussion (FGD) with 20 farmers selected randomly across the two villages. The important criteria as used by Otieno, Alwenge, and Okumu (2019): maize varieties, availability and adoption; maize cropping systems (e.g. spacing, mono-cropping, intercropping); Fertilizer use (e.g. rate, blend, timing and placement); Soil fertility management practices (e.g. soil acidity, organic matter, erosion, soil structure); common biotic and abiotic stresses (e.g. disease, pest, weeds, drought, flooding); and Post-harvest maize handling (e.g. drying, storage, market access) were adapted in guiding the discussion. The data generated were then analyzed and compared with those gathered from secondary sources. Because of the small sample size (n=20), the data were analyzed using excel- calculation of percentages. The secondary data used were from previous research publications available online. These materials were searched, downloaded, read, cited and referenced as the best practice.

3. RESULTS AND DISCUSSION

Selection and adoption of improved varieties

From the research, it was noted that farmers have low access to improved varieties adapted to the region, particularly short maturing and high yielding varieties. As a result, they produce a mixture of varieties: local (e.g. Tulbuliya, Tinpakhiya), open-pollinated varieties (OPV) (e.g. Shweta, Mashina Pant Makka) and hybrid (e.g. Cargill) (Joshi, 2005). According to Kumar, Srinivas, and Sivaramane (2013) and Joshi et al. (2016), only about 50% of maize growers are aware of the existence of hybrid seeds. This does not necessarily mean they are currently producing them in the region. As confirmed during the focus group discussion (FGD), only 5% of farmers were producing relatively new improved maize varieties. The adoption trends of these hybrid varieties were found to be greatly influenced by the season-low adoption of hybrids in the monsoon compared to the winter season. This is largely due to frequent flooding during the Kharif/monsoon season that negatively impacts on the current hybrids available. Again, the hybrids currently used by farmers are old and could be having reduced genetic potential for any meaningful productivity. According to Singh et al. (2014), only 21.25% of farmers are using varieties released less than 5 years ago in the region.

Land preparation: Timing, method of preparation, and tillage systems

The methods of land preparation vary depending on the economic status of the farmer and land size owned. It was observed that farmers use both tractors and animals to carry out 2 plows before planting. Joshi (2005) and Kumari, Meena, and Singh (2015) also reported that farmers carry out 2-3 plows using either machine or animal powered implements depending on the land size and economic status. Despite several benefits of conservation agriculture (as defined by reduced land tilling and permanent ground mulch cover) in soil and water management, its adoption was found to be low among smallholders in the region. According to Keil, D'souza, and McDonald (2017), only about 40% of farmers are aware of the conservation agriculture technology. The authors went further to note that the majority of conservation agriculture adopters are those who are educated and own large tracts of land in the region. During this research, 80% and 100% of farmers interviewed do not use raised beds and practice reduce tillage, respectively, for maize production despite the likely occurrence of flash floods and droughts in the region.

Sowing: Seed treatment, spacing, and seeding rate practices

From the research, farmers were observed to use two categories of seeds based on the sources- local or improved seeds. The local seeds are not treated with pesticide or fungicide. The untreated seeds are therefore predisposed to early attacks by soil-borne pests and diseases compared to commercially produced and packed seeds. Farmers were also reported to use up to 20% more seeds (Kumari, Meena, and Singh, 2015). This high seeding rate could be due to low germination percentages that consequently increase the cost of production. The low germination percentages could be as a result of poor quality of farmer-saved seeds- low standards during production and storage. Again, farmers were observed to use high-density planting- all farmers interviewed practiced narrow spacing of 45-50 cm by 17-20 cm compared to feasibly recommended spacing of 60-75 cm X 25-20 cm spacing. Such high maize population densities are likely to cause competition for limited water and nutrient resources thereby negatively impacting on yields.

Nutrient management: Fertilizer type, rate, time and placement method

Dominant soil types in East Champaran have good water-holding capacity (Sattar et al., 2013). The deficiency of nutrients in India has been reported. Grewal and Sharma (1995) have reported low levels of potassium concentration in Indian farms due to the high alluvial content that increase the rate of leaching. The dominant soil type is likely to be the reason for low concentrations of mobile nutrients across the farms. In addition to constant plant uptake, if all these nutrients are not adequately replenished, the soils could have serious low nutrient levels with a great yield impact. The general soil pH was found to be good for maize production at 6.7-6.9 with other characteristics as shown in the Soil Grid App (ISRIC, 2019). However, intensive soil analysis is yet to be done in the region to inform farmers on their current status of the soils. Based on the information available at the Government of India Farmer's Portal (https://www.farmer.gov.in/FarmerHome.aspx), there is no soil analysis data that exist for East Champaran District. This implies that the current soil fertility management practices applied by farmers in the region could be abstract and not well informed. According to Kumar, Srinivas, and Sivaramane (2013), use of fertilizers is highly influenced by the variety of maize grown: 50-70 kg fertilizer per hectare under local varieties to about 200 kg fertilizers per hectare under hybrid varieties. From FGD, all farmers interviewed were found to apply about 74-86 kg DAP, 74 kg Potash, 190-222 kg urea per hectare for maize production. Use of zinc-based fertilizers was also noticed among farmers with a common application rate of about 15 kg/ha. These rates are supposed to produce more than the current 2 t/ha yields obtained if used efficiently. High inefficiencies in fertilizer use could be due to the current placement method and timing practiced by the farmers. Broadcasting of fertilizer has been found to result in high nutrient losses and low efficiencies compared to the localized/point application method (Hoff et al., 1981; Daverede et al., 2004). Again, instead of carrying out the basal application during planting, farmers were reported to apply most of their fertilizers during field preparation- a practice that could highly expose the nutrients to greater leaching erosion, and volatilization losses even before maize plants have developed proper roots for absorption.

Water stress: Droughts and floods

Generally, the amount of rainfall received across Bihar State is on the decline at a rate of 8-15% per decade (Singh et al., 2014). According to Singh and others, despite recording higher than normal (based on 30 years average), East Champaran District has shown the highest variation in seasonal rainfall at about 26% with 40% chances of having a drought in a season. Such high variations pose uncertainty in rainfall dependent monsoon maize crop. From the FGD, all farmers (100%) acknowledged drought to be a major challenge affecting monsoon production. Again, mitigation strategies are not well applied by farmers- there were no soil water conservation measures (characterized by minimum tillage, crop rotation, and permanent soil cover) practiced. According to Ramasubramaniyan, Vasanthakumar, and Hansra (2016), about 72.6% and 75.1% of farmers are aware of minimum tillage and permanent soil cover strategies, respectively, across India. However, in terms of adoption, Ramasubramaniyan, Vasanthakumar, and Hansra found that only 11.5% of farmers adopted minimum tillage, 27.6% of farmers adopted permanent soil cover across all cross all the agro-ecological zones in India. This means that the majority of farmers risk losing their crops whenever soil moistures go below plant available levels.

Also, the Bihar State is known to flood whenever there is much rain causing significant yield losses. The topography is nearly flat- about 92% of the region has flat to gently slope gradient (Joshi, 2005; Rakesh Singh, 2013). This exposes the crops to waterlogging during heavy rainfall resulting in yield losses. In a neighboring and more similar State, Uttar Pradesh, surface waterlogging is common during normal planting times causing 60-80% maize yield losses (Joshi et al., 2005). This situation has greatly influenced the adoption of hybrid varieties- all farmers interviewed reported that their adoption preference for local varieties is due to the crops' ability to tolerate floods compared to hybrids.

Maize agronomy and weed management

Farmers tend to have poor knowledge of best maize production practices during the monsoon season. 100% of farmers interviewed were observed to be using high-density planting (spacing at 45-50 cm by 17-20 cm) despite declining rainfall amounts across the monsoon season. Again, weed management is not timely and properly done. According to Joshi et al. (2005), farmers carry out 1-2 weeding regime for the entire maize seasons. While conversing with farmers during FGD, it was observed that single weeding is the commonly practiced trend in the district- 70% of farmers currently practicing it. This finding is similar to Kumari Meena and Singh (2015) who reported that farmers only carry out weeding once when crops are 3-4 weeks old. This leads to high competition for growth factors such as limited soil moisture, nutrients, and space. Various weed species have been reported in maize fields both under mono-cropping and intercropping systems. Haji et al. (2012) reported Cynadon dactylon, Dinebra retroflexa, Echinocloa colanum, Elusine indica, and Cyperus rotundus to be among the most important weeds in maize fields. They also noted that Parthenium hysterophorus, Commelina bengalensis, Portulaca oleracea, Cynotis cuculata, Phylantus niruri and Amaranthus viridis are the common broad-leaved weeds in maize fields. Other researchers have reported many grass and broadleaved weeds in maize fields (Madhavi et al., 2014; Mukherjee and Rai, 2015; Stanzen et al., 2016; Kakade et al., 2016; Kumar et al., 2017). These weed species if not well and timely controlled could lead to significant maize yield losses. According to Kumar, Srinivas and Sivaramane (2013) and Joshi et al. (2005), untimed and poor management of common weeds such as C. dactylon, Echinochloa, and Cucurbitaceae family could cause 35-40% maize yield loss in Bihar State. Other researchers have reported as high as 93% maize yield loss in India (Jat et al., 2012; Kumar et al., 2015; Yakadri et al., 2015; Kakade et al., 2016). These reported yield losses vary depending on crop spacing (wide versus narrow) (Rai et al., 2018) and weed species and intensity (Hawaldar and Agasimani, 2012). Other factors such as crop tolerance levels, soil fertility, and rainfall availability could as well influence the level of damages caused by weeds.

Pest and disease attacks

High attacks on maize by both insect pests and diseases were expected during the monsoon season due to prevailing favorable conditions. Kumar, Srinivas, and Sivaramane (2013) reported that the monsoon conditions favor pest and disease attacks leading to 10-15% yield losses in the region. Common pests attacking Kharif maize include Pink borer (*Sesamia inferens*), shoot fly (*Atherigona sp*.), Stem borer (*Chilo partellus*), Termites (*Odontotermes obesus*), and Chafer beetle (Manish Upreti, 2019). Farmers themselves (100% of farmers interviewed) confirmed that stalk borer is the most important field pest affecting maize crops. According to Jalali and Singh (2002), Chilo partellus is a key pest resulting in 90-95% of the total damage if left uncontrolled during the Kharif season. Incidences of Termites were also observed in some fields (only 2% of farmers interviewed), though the effect is low and not considered a serious threat by farmers.

Commonly found diseases include Turcicum leaf blight (*Exserohilum turcicum*), and Common rust (*Puccinia sorghi*) (Manish Upreti, 2019). About 90% of farmers interviewed reported disease incidences though with negligible yield losses. Leaf blight is a widespread disease with up to 70% maize yield loss if left unchecked in Bihar State (Yashitola, 2003; Shankara, Pradhan, and Patole, 2017).

Harvesting and postharvest practices

Maize is ready for harvesting in September depending on when the crops are planted and the variety used. But farmers do not harvest during this period as they leave the crops to dry in the fields. This practice attracts high pest and aflatoxin infestation. Manual hand harvesting method is usually carried by women who form the main farm workforce. During storage of maize, farmers were found to still rely on traditional structures like gunny bags or wooden and earthen drums leading to about 10-25% yield loss due to attacks by *Rhyzopertha dominica* (Lesser grain borer), *Oryzaephilus surinamensis* (Saw-toothed grain beetle) insect pest (Narang, 2002; Sharon, Abirami, and Alagusundaram, 2014; Ajaykumara, 2015). These insects also cause secondary infections and may lead to total losses within three months of storage under high infestation. Quality losses are also high due to these poor storage structures and the season of production (Kharif): High and dangerous aflatoxin concentration > 20 micrograms per kilogram are common under storage and field conditions during Kharif season. According to Sinha (1990), maize grains from fields and stores have 47% and 43% aflatoxin incidences, respectively.

CONCLUSION

Maize production is affected by numerous biotic and abiotic related challenges in East Champaran District. The solution to these constraints calls for stronger research-extension linkage that would ensure better development and dissemination of better technologies and practices for adoption. Among these constraints, priority research topics include drought, soil infertility, stalk and cob borer, and fall armyworm and aflatoxin infection management. The research towards these challenges should be region specific to avoid the blanket type of recommendations that may not last long.

ACKNOWLEDGMENT

My sincere appreciations go to all farmers who dedicated their time to have the focused group meetings successful.

References

[1] Ajaykumara, K. M. (2015). Biology and management of Rhyzopertha dominica (F.)(Bostrichidae: Coleoptera) on maize (Doctoral dissertation).

[2] C.M. Parihar, S. L. Jat, A.K. Singh, R. Sai Kumar, K.S. Hooda, Chikkappa G.K. and D.K. Singh. Maize Production Technologies in India. DMR Technical Bulletin 2011/---. Directorate of Maize Research, Pusa Campus, New Delhi-110 012. Pp 30.

[3] Food and Agriculture Organization of the United Nation (2019) Maize production quantity in India. Retrieved from http://www.fao.org/faostat/en/#data/QC on 12th February 2019.

[4] Government of India (2013) Economic Survey of Bihar. Available at http://indiabudget.nic.in/budget2012-2013/

[5] Hawaldar, S. and Agasimani, C.A. (2012). Effect of herbicides on weed control and productivity of maize (Zea mays L.). Karnataka J. Agric. Sci., 25(1): 137- 139.

[6] ISRIC- World Soil Information: SoilGrids — global gridded soil information. Available from www. https://soilgrids.org

[7] Jalali SK, and Singh SP. (2002) Seasonal activity of stem borers and their natural enemies on fodder maize. Entomon; 27(2):137-146.

[8] Jat, R.K., Gopar, R. and Gupta, R. (2012). Conservation agricultural in maize-wheat cropping systems of eastern India: Weed dynamics and system productivity. In: Extended summaries Vol. 3, 3rd International Agronomy Congress, November 26-30, 2012, New Delhi, India.

[9] Joshi, P. K. (2005). Maize in India: Production systems, constraints, and research priorities. CIMMYT.

[10] Joshi, P. K., Roy, D., Sonkar, V., & Tripathi, G. (2016). Technologies for Maize, Wheat, Rice and Pulses in Marginal Districts of Bihar and Odisha. In Technological and Institutional Innovations for Marginalized Smallholders in Agricultural Development (pp. 323-367). Springer, Cham

[11] Joshi, P.K., N.P. Singh, N.N. Singh, R.V. Gerpacio, and P.L. Pingali. 2005. Maize in India: Production Systems, Constraints, and Research Priorities. Mexico, D.F.: CIMMYT

[12] Kakade, S.U., Deshmukh, J.P., Bhale, V.M., Solanke, M.S. and Shingrup, P.V. (2016). Efficacy of pre and postemergence herbicides in Maize. Extended Summaries Vol. 1: 4th International Agronomy Congress, Nov. 22–26, 2016, New Delhi, India. pp - 442-443

[13] Keil, A., D'souza, A., & McDonald, A. (2017). Zero-tillage is a proven technology for sustainable wheat intensification in the Eastern Indo-Gangetic Plains: what determines farmer awareness and adoption?. Food Security, 9(4), 723-743.

[14] Kumar, A., and Singh, K. M. (2017) A Study on Maize Production in Samastipur (Bihar): An Empirical Analysis.

[15] Kumar, B., Prasad, S., Mandal, D. and Kumar, R. (2017) Influence of integrated weed management practices on weed dynamics, productivity and nutrient uptake of rabi maize (Zea mays L.). International Journal of Current Microbiology and Applied Sciences., 6 (4): 1431-1440.

[16] Kumar, R., K. Srinivas and N. Sivaramane (2013), Assessment of the maize situation, outlook and investment opportunities in India. Country Report – Regional Assessment Asia (MAIZE-CRP), National Academy of Agricultural Research Management, Hyderabad, India.

[17] Kumar, R., Saini, J.P., Chadha, S, and Kumar, R. (2015). Weed suppression in maize with legume intercrops and sowing pattern under organic conditions in NW Himalayas. Green Farming., 6 (1): 161- 163.

[18] Kumari, M., Meena, L. K., & Singh, R. G. (2015). Problems and Prospects of Maize Crop in Eastern Zone of Bihar. International Journal of Agricultural Science and Research, 5(2), 137-146.

[19] Madhavi, M., Ramprakash, T., Srinivas, A., and Yakadri, M. (2014). Topramezone (33.6% SC) + Atrazine (50%) WP tank mix efficacy on maize. The Biennial conference on "Emerging challenge in weed management" Organized by Indian Society of Weed Science.15-17, February.

[20] Manish Upreti (2019) MAIZE PRODUCTIVITY AND USE OF CROP PROTECTION PRODUCTS IN INDIA: Importance of maize cultivation in India. Available at https://www.kleffmann.com/en/kleffmann-group/news--press/press-releases/india---maize-productivity-and-crop-potection/

[21] Mukherje, P.K., and Rai, A. (2015). Weed management in no-tilled dibbling maize within rice residue. 25th Asian-Pacific Weed Science Society Conference on "Weed Science for Sustainable Agriculture, Environment and Biodiversity", Hyderabad, India during 13-16 October 2015. pg. 148.

[22] Narang, D.D. 2002. Banish the Pests Feeding on our Grain. In the Tribune September 23, Chandigarh India.

[23] Otieno, H. M., Alwenge, B. A., & Okumu, O. O. (2019). Coffee Production Challenges and Opportunities in Tanzania: The Case Study of Coffee Farmers in Iwindi, Msia and Lwati Villages in Mbeya Region. Asian Journal of Agricultural and Horticultural Research, 1-14.

[24] Parihar, C. M., Jat, S. L., Singh, A. K., Kumar, R. S., Hooda, K. S., GK, C., & Singh, D. K. (2011) Maize production technologies in India.

[25] Rakesh Singh (2013) Ground Water Information Booklet East Champaran District, Bihar State

[26] Sattar, A., Kumar, M., Bobade, P., and Chandrawanshi, S. (2013). Assessing the length of growing season and drought incidence in Bihar. Journal of Agrometeorology, 15, 1-3.

[27] Shankara, K., R.S. Pradhan, and Patole, S.P (2017) Yield Loss Assessment due to Turcicum Leaf Blight of Maize Caused by Exserohilum turcicum. Int.J.Curr.Microbiol.App.Sci. 6(10): 2888-2891.

[28] Sharon, M., Abirami, C. V., & Alagusundaram, K. (2014). Grain storage management in India. Journal of Postharvest Technology, 2(1), 12-24.

[29] Singh, S. K., Singh, K., Singh, R., Kumar, A., and Kumar, U. (2014) Impact of Rainfall on Agricultural Production in Bihar: A Zone-Wise Analysis.

[30] Sinha, K. K. (1990). Incidence of mycotoxins in maize grains in Bihar State, India. Food Additives and Contaminants, 7(1), 55–61.

[31] Stanzen, L., Kumar, A., Sharma, B.C., Puniya, R. and Sharma, A. (2016). Weed dynamics and productivity under different tillage and weed-management practices in maize (Zea mays)- wheat (Triticum aestivum) cropping sequence.Indian Journal of Agronomy., 61 (44): 449-454

[32] The government of Bihar: BIHAR: Agriculture Contingency Plan for District: East Champaran. Available at: http://krishi.bih.nic.in/

[33] Yakadri, M., Rani, P.L., Prakash, T.R., Madhavi, M. and Mahesh, M. (2015).Weed management in zero till on maize. Indian Journal of Weed Science., 47(3): 240–245.

[34] Yashitola, D., (2003). Cloning and characterization of xylanase genes from phytopathogenic fungi with a special reference to Helminthosporium turcicum, the cause of northern leaf blight of maize. Academic thesis, University of Helsinki, Finland.