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Agrotechnological Options for Upscaling Agricultural Productivity in Eastern Indo Gangetic Plains under Impending Climate Change Situations: A Review

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ABSTRACT

This review article scrutiniz some of the vibrant technologies developed/ refined/ adopted to improve agricultural system productivity in the Eastern Indo Gangetic plains. Efficient agronomic research and technological development for improving agricultural productivity in eastern region are the only options to feed our people under this difficult situation. These tested and refined technologies are not only capable of improving productivity in a sustainable manner but are equally efficient in minimizing the outbreak of insects and disease pests. Important agro-technology developed and refined for Eastern Region conditions are briefly discussed in this article.

***Keywords*:** Agro technology, Contingency Agronomy, Crop Diversification, Conservation Agriculture, Eastern Indo Gangetic Plains

INTRODUCTION

Eastern Indo Gangetic Plains is currently facing problem of feeding ever-increasing population under the climate change scenario. IPCC projected minimum 1.8 °C increase in temperature by 2100 above 1990 level and confirmed that the global average temperature increased by 0.74 °C over the last century, which is likely to pose a potential threat to agricultural production and productivity and affects the crop yields due to incidence of plant diseases and weeds, pests as well. There is very good chances of decrease in rice yield up to 5 per cent for every 1 °C rise in temperature above 32 °C (IPCC, 2007). System approach is also an efficient and excellent tool for effective disease pest management in general and especially for soil borne pathogens, under changing climate scenario (Ali *et al*., 2012 and Singh *et al.,* 2011). A number of agro-technology has been developed by ICAR Research Complex for improving agricultural system productivity. The Eastern Indo Gangetic Plains comprises of Eastern UP, Bihar, West Bengal, and plain parts of Assam (Annonymus, 2001-2011).

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There is a large gap between potential and productivity of major crops (Bastia *et al.,* 2008 and Singh *et al.,* 2012a). A sizeable part of the cultivated area in eastern region does not have provision for assured irrigation; therefore, even short drought spells adversely affect the stability of agricultural production. The region suffers from various biophysical constraints such as water congestion and flooding during kharif (Singh *et al.,* 2012b). The region is characterized by socio-economic constraints like small and fragmented farm holdings, lowest per capita availability of land, inequitable agrarian structure, resource poor farmers, and poor infrastructure facilities like roads, communication power supply, storage and marketing (Joshi, 1998 and Singh *et al*, 2011). The characteristic feature mentioned all together lead to poor system productivity of agricultural as a whole including crop production. Further nutrient use efficiency is also low except nitrogen (40-45 %), other are much lower in the range (< 20%) (Ali *et al.*, 2012 and Singh and Kumar, 2009).

Global warming poses a potential threat to agricultural production and productivity throughout the world and this might affect the crop yield, if suitable measures are not taken, crop yield might be decreased sharply by 2050 (Singh *et al.,* 2012b). Keeping in view the potentiality of agronomic research and technological development for the agricultural development, this paper discusses different agronomic practices and agricultural technology developed for Eastern Indo Gangetic Plains under following subheads.

- Assessment of Agricultural Potential of Region
- Application of developed agro-technologies
- Agro-technologies developed and refined suitable for Region
- Crop production strategies to address climate change
- System approach to combat eminent climate change
- Contingency agronomy for flood and drought
- Conclusion

Assessment of Agricultural Potential of Region

Even though the region has rich rain (rainfall varies from 1025 mm to 2823 mm), surface and ground water resources they are grossly underutilized, and therefore a large proportion of the cultivated area does not receive any irrigation water. The land holding size of eastern region ranges from 0.3 to 0.5 ha, coupled with fragmented lands makes situation worse for application of any technology directly to the field. Owing to poor utilization of water resources, the cropping intensity in the region is low. There is a large gap between potential and productivity of major crops that can be improved by adopting efficient crop management technologies developed at ICAR research complex for eastern Region Patna (Singh et al., 2011). Under these circumstances efficient agronomic practices based on sound footing on research and technological development often offer the opportunity to alter the environment, the condition of the host, and / or the behavior of the causal agent, to achieve economic management of the disease. Integration of cultural practices, host resistance and pesticides or bio-control agents may be necessary to provide option for controlling economically important plant diseases (Joshi, 1998, Mondal et al., 2004 and Singh et al., 2011).

Application of Developed Agro-technologies

About 70% of land is prone to natural calamity viz., water logging, flood or drought. The highly fertile land, rich water resources, biodiversity and manpower can be used in an integrated manner in a farming system mode by recycling of wastes to secure high resource use efficiency and improved livelihood. The major research focus would be on multi-dimensional and multi-commodity, multi-disciplinary research in a program matrix involving land and water management, crop management to take advantage of complementarities among them for improving overall resource productivity, resource or input use efficiency and livelihoods in the eastern region (Sahaa *et al.,* 2007 and Singh *et al.,* 2012a). Major thrust areas of agronomic research include (a) Conservation Agriculture (b) Nutrient management (c) Water management and (d) Climate resilience agronomy (Singh and Singh, 2013).

Agro-technologies Developed and Refined for the Region

The resource use efficiency at present level is poor due to lack of adoption of appropriate agronomic management practices developed through well planned efficiently executed research programme (Anonymous, 2001- 2011). Modern agronomic research must be dedicated on efficient natural resources management viz., sustainable land and water management, crop management to take advantage of complementarities among them (Singh *et al,* 2011). Agronomic research conducted and technologies generated for improving resource or input use efficiency and to improve overall resource productivity, and livelihoods in the eastern region are discussed below:

Conservation Agriculture

Rice and wheat is most important cropping system in Eastern Indo-Gangetic plains encompassing an area of 7.49 million ha (M ha), out of the total rice-wheat area of 10.5 million ha in the country. The yield of rice and wheat has increased in Bihar, but the yield of wheat in the state of West Bengal has registered a negative growth. To sustain agriculture production and productivity conservation agriculture may prove vital. The RWC-CIMMYT collaborative USAID/IFAD Projects were started in May 2004 at ICAR Research Complex for Eastern Region, Patna. Second generation Resource Conservation Technologies (RCTs) were taken up in kharif 2004 and rabi (2004-05) season. During kharif season, direct seeded rice was taken up in 8.28 ha among 20 farmers. N-management was done through leaf colour chart (LCC) and 50 kg/ha N was saved. Brown manuring was done through co-culture of

Sesbania. The weedicide 2-4,D was used to kill *Sesbania* when it was 25 – 30 days old. The dropped brown *Sesbania* leaves added N in the rice field. The saving in N through brown manuring of *Sesbania* was 34 kg/ha. Maize – Potato was taken through RCTs on raised bed in 7.32 ha area among 72 farmers. Different methods of RCTs like residue management (6.4 ha), intercropping (2.0 ha), traffic control (12.77 ha), paired row (3.3 ha) and surface seeding of wheat (6.62 ha) were demonstrated (Anonymous, 2001- 2011 and Joshi, 1998).

Tillage management practices for rice – wheat cropping system

Three treatments on summer tillage (Deep Summer Ploughing (DSP) every year, DSP in alternate years and no DSP), two tillage treatments (Conventional tillage and Zero tillage (ZT)) and two moisture regimes (normal water supply and limited water supply) were evaluated. DSP fields have more moisture and less penetration resistance, which provided conducive environment for root development. Root length of Zero tilled wheat has edge over conventional tillage under DSP and non-DSP. Plant height of wheat in DSP every year was highest and weed emergence during entire crop stage was lowest in deep summer ploughed fields. DSP alternate year resulted in significantly higher grain yield of wheat (4.14 t/ha) over non-DSP (3.93 t/ha). Zero till method of crop establishment also performed better in respect grain yield (4.18 t/ha) was significantly higher over conventional tillage (3.99 t/ha) (Table 1) (Singh *et al.,* 2011).

Efficient rice cultivars for resource conservation system

Different rice cultivars were evaluated under two resource conservation technologies (RCTs) i.e. dry seedling with 50 % mulch and dry seedling without mulch. The crop was sown as zero till direct seeded rice (ZTDSR) and was compared with transplanted rice (wet seedling /puddle condition). Few promising varieties i.e. IET 21299, IET 20800 were identified for mulch condition whereas, BPT 5204, IET 21299, Silwamani were found promising without mulching condition (Table 2).

Nutrient management

Inadequate supplies of essential plant nutrients have major impact on crop yields and are one of the major crop production factors that can be readily managed. An insufficient supply of any one or more of these nutrients can have a detrimental effect on plant growth and, ultimately crop yield. Four major nutrients nitrogen, phosphorus and, to a lesser degree, potassium and sulphur are likely to be a concern for crop production on mineral soils in most areas of country. The micro nutrients are also important if soils are deficient in any one or more of them. If any of the essential plant nutrients are deficient then plant cannot perform well and crop are unable to reap optimal economic yield (Sahaa *et al.*, 2007; Singh and Kumar, 2009 and Singh *et al.*, 2013a).

Nitrogen management through LCC in puddled and direct seeded rice

LCC helped farmers to measure the leaf colour intensity, which is directly related to leaf

Table 1: Effect of tillage on yield attributes and yields of wheat in Patna (2004-05)

Tillage Treatment	Plant Height (cm)	Weed dry weight (g/m^2)		No. of tillers/m^2	Ear head Length (cm)	No. of grains /Ear head	1000 grain Weight (gm)	Grain yield (t/ha)
		Tillering	Flowering					
Summer Tillage								
DSP every year	84.43	05.13	15.70	803.25	16.65	37.25	42.15	4.04
DSP alternate	80.49	17.25	16.78	677.50	13.53	40.35	40.68	4.14
Non DSP	80.79	35.75	39.70	653.75	14.53	38.29	40.88	3.93
LSD (P = 0.05)	02.63	20.42	16.00	099.67	02.08	02.07	00.98	0.136
Crop establishment tillage								
Zero tillage	82.38	16.42	14.87	717.83	14.30	39.07	42.09	4.18
Conventional Tillage	41.43	22.33	33.25	705.17	14.17	38.19	40.37	3.99
LSD (P = 0.05)	NS	NS	NS	NS	NS	NS	01.30	0.157

Source: Anonymous. 2001- 2011. Annual Reports. ICAR Research Complex for Eastern Region, Patna.

Table 2: Evaluation of rice cultivars under different resource conservation system

Sl.	Varieties	Yield (q/ha)		
		Dry seeding with 50% mulch	Dry seeding wihtout mulch	Wet seeding/ puddle condition
1.	IET 20760	19.71	17.68	22.44
2.	IET 21299	29.85	30.37	30.85
3.	RM-1	20.37	21.51	20.90
4.	BPT 5204	26.28	31.38	26.17
5.	IET 20800	29.19	27.86	29.67
6.	IET 20761	17.63	19.97	22.38
7.	Silwamani	25.50	29.82	24.77
8.	IET 21248	16.95	20.77	20.73
9.	Swarna Sub-1	23.89	29.40	24.65
	SEM ±	0.255774	0.211745	0.243113
	LSD (P = 0.05)	0.766844	0.634840	0.728887
	CV	1.904492	1.442879	1.702806

Source: Anonymous. 2001- 2011 Annual Reports. ICAR-Research Complex for Eastern Region, Patna.

chlorophyll content and leaf nitrogen status. The timings of nitrogen top dressing could easily be determined based on soil N supply and crop demand. This simple tool helped farmers to reduce the excess use of nitrogen fertilizers and led to fertilizer savings of up to 45 kg/N/ha (Mondal *et al.,* 2004 and Singh and Singh 2013).

The use of brown manuring

Brown manuring practice was introduced where *Sesbania* crop @ 20 kg/ha was broadcasted three days after rice sowing and allowed to grow for 30 days. Co-cultured *Sesbania* crop was dried by spraying 2, 4-D ethyle ester. The dried leaves of *Sesbania* fell on the soil and decomposed very fast to supply N, dry matter, soil organic carbon and other recycled nutrients to the soil. The practice led to reduction of weed population by nearly half without any adverse effect on rice yield. Pest attack was also reduced (Mondal *et al.,* 2004; Rana *et al.*, 2003 and Singh and Kumar, 2009).

Balanced nutrient management in surface seeded wheat

Surface seeding (SS) of wheat seed @ 160 kg/ha is done in low lands where excess soil moisture does not allow tillage operation till end of December. Wheat seed is normally broadcasted in standing rice crop 10 – 15 days before harvesting. And sometimes sowing of wheat is done immediately before harvest of rice. With SS, use of P and K was introduced as an intervention to evaluate the effect of balanced fertilizer dose. There was 1.12 t/ha higher wheat yield over conventional surface seeding without P & K giving a net benefit of Rs.4780/ha (Kumar *et al.*, 2014; Sahaa *et al.*,2007 and Singh and Kumar, 2009).

Nutrient and Water dynamic in rice based cropping system

Evaluation of two rice based cropping systems i.e. rice-wheat-green gram (C_1) and rice-lentil-green gram (C_2) in combination with irrigation and nutrient. it was noticed that applications of optimum levels/doses of fertilizer produced significantly higher yield (11.49 t/ha) than sub-optimum levels and the increase was to the tune of 13.74 per cent. Maximum rice yield equivalent was recorded under rice-wheat-green gram system (11.16 t/ha), which was at par with rice-lentil-green gram system (10.44 q/ha). There was a significant variation among cropping systems, levels of irrigation, fertilizations and its interactions during 1st crop cycle, Among cropping systems, maximum rice yield equivalent was recorded in rice-wheat-green gram (12.02 t/ha) followed by rice-lentil-green gram (11.21 t/ha) based on three-crop cycles. Among the levels of irrigation and fertilizer, maximum rice yield equivalent was recorded at optimum (recommended nitrogen only) level (12.11 t/ha & 12.35 t/ha) followed by sub optimum (half nitrogen only) level (11.12 q/ha & 10.88 t/ha), respectively (Table 3). Pulse based cropping system used water more efficiently (78.90 & 75.62 kg/ ha/cm) than cereal based cropping system (74.51 & 71.42 kg ha/cm) at both the level of irrigation Uptake of NPK in cereal dominated cropping system was more than pulse dominated cropping system. Uptake of nutrients at optimum level of irrigation and fertilizer was more than sub-optimum level Highest net return of Rs. 32, 985/ha and 27, 352/ha was obtained in rice-lentil-green gram followed by rice-wheat-green gram (Rs. 29, 328/ha and 25, 865/ha) at optimum and sub-optimum levels of irrigation and fertilizers, respectively during 2001-02 (Anonymous, 2001- 2011; Kumar *et al.,* 2013 and Sahaa *et al.*, 2007). In another study to optimize fertilizer and water regime for better crop growth as well as nitrogen and potassium disposition in rice crop was taken at ICAR Patna. The experiment was laid out in split plot design with the rice variety *Sita* and 0, 40, 80 and 120 kg/ha nitrogen levels as main plot treatments and 0, 30, 60 and 90 kg potassium as sub plot treatments in three replications. Potassium concentration increased with increase in potassium levels however, little difference was seen between 60 and 90 kg K levels. Grain yield of rice was recorded after harvesting and statistically analysed to know the effect of different treatments. There was an increase in the yield with both nitrogen as well as Potassium levels. Highest grain yield (7.53t/ha) was obtained with 80 kg nitrogen and 60 kg Potassium (Kumar *et al.,* 2014 and Singh *et al.,* 2014).

Managing nutrients to produce quality tobacco leaves

Studies on long term manurial trial on chewing tobacco revealed that two irrigations given at 30 and 60 days after transplanting produced higher total cured leaf of 1558 kg/ha and first grade leaf of 380 kg/ha than the rainfed crop. However, irrigated crops also attained greater length and width of leaf and puckering scores. Application of 112 kg N/ha, 112 kg P_2O_5/ha and 112 kg/ K_2O/ha gave higher total and first grade leaf yields than the control. Total leaf yield increased by 225, 22 and 8 per cent due to application of nitrogen, phosphorus and potassium fertilizers, respectively, over no application of fertilizers to the crop. For first grade leaf, the increase in yields were 174, 11 and 40 per cent due to nitrogen, phosphorus and potassium applications, respectively, over control. Quality of leaf i.e. spangling and puckering scores was also higher in fertilized plots than the unfertilized plots (Singh and Singh, 2013).

Nutrient management in chewing Tobacco based inter-cropping system

An experiment was conducted for three years with 15 treatment combinations consisting of three intercrops (garlic, rajma & potato) and five fertility gradients *i.e.* 100, 75, 50, 25 and 0 per cent of the recommended dose for the three intercrops to find the recommended dose of fertilizer for tobacco. Pooled analysis of yield data of tobacco over three years revealed that among the three intercrops, garlic performed at par with rajma and produced highest total and first grade cured leaf. Among the fertility levels, application of 75 per cent recommended dose of fertilizer to intercrops produced total and first grade leaf yields on par with 100 per cent of the recommended dose. Data on mean yields of intercrops showed that garlic gave 1.18 t/ha, rajma 0.79 t/ha and potato 6.6 t/ha over three years. Application of 100 per cent the recommended dose of fertilizer to intercrops, gave highest yields of intercrops. Net return was highest (Rs. 42,948/ha) under Tobacco + Garlic intercropping systems followed by Tobacco + Rajma intercropping system. The difference between the two intercropping systems was Rs. 1,367/ha. Spangling, puckering and maturity scores were significantly higher when tobacco was intercropped with garlic and rajma than the tobacco intercropped with potato. Application of 75 per cent of the recommended dose of intercrops gave highest spangling score being on par with application of 100 per cent of the recommended dose for the intercrops. In case of puckering and maturity scores, application of 50 per cent of the recommended dose of fertilizers for intercrops, gave statistically same scores as 75 and 100 per cent of the recommended dose of fertilizers for the intercrops (Anonymous, 2001- 2011 and Singh *et al.,* 2011).

Water management

Efficient management of water is of utmost importance for sustaining and increasing the production. Drought stress has become the major limiting factor on plant growth and yield. Water deficit during the reproductive growth is considered to have the most adverse effect on crop productivity. Most of the crops are best adapted to the relatively cool growing conditions. Hot, dry spells result in wilting of the plants and may reduce seed set. Experiments on various aspects of water management of important crop has been conducted and salient achievements are as under

Irrigation schedules and nutrient management for wheat

Three recommended irrigation schedules against farmer practice at five integrated NPK management levels were evaluated in heavy soils of south Bihar. The results revealed that there was no significant difference among the irrigation schedules on physiological parameters and growth characters like plant height, tillers/m^2. Yield and its attributes at various irrigation schedules were at par. However, 1000-grain weight and grain yield was significantly higher under 0.9 IW/CPE ratio over farmers' practice. Under nutrients levels, 125 percent NPK had given significantly higher yield over 75 per cent NPK + FYM @ 15 t/ha. Highest yield of 3.66 t/ha was recorded under 125 per cent NPK and found at par with 100 per cent NPK by fertilizer (Table 3).

results indicated that germination of wheat was adversely affected by excess soil moisture. There are inherent differences amongst wheat varieties to withstand excess soil moisture condition. The average root diameter of wheat varieties was also adversely affected by soil moisture content. Variety HUW – 234 was found to be less susceptible in comparison to other varieties included in this study to excess soil moisture at the time of sowing. Surface seeding was found to be most effective for establishing wheat under excess soil moisture condition (Anonymous, 2001- 2011 and Singh *et al.*, 1997).

Tillage and water management studies in wheat

While evaluating three methods of wheat establishment (conventional, zero-tillage and raised bed planting) in combination with four depths of irrigation water (3, 5, 7 and 9 cm) root parameters (area, length, surface density, diameter, length density and volume density) at tillering and flowering stages were highest under raised bed planting. Root parameters were found higher under 5 and 7 cm depth of irrigation. Better yield and yield attributes were found with Zero

Table 3: Yields attributes and yield of wheat as affected by irrigation and nutrient

Treatments	Ear head per m^2	Length ear head (cm)	Grain number per ear head	Grain weight per ear head	1000 grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Irrigation Schedules								
Irrigation at Critical stage (CRI+LT+M+D)	219.3	10.3	56.1	27.1	45.36	3.12	5.04	38.57
Irrigation at 50% ASM	200.1	9.8	52.6	26.8	44.78	3.09	5.13	38.35
Irrigation at 0.9 IW/CPE	196.1	10.2	56.9	26.4	45.33	3.26	5.16	38.45
Farmers practice (3 irrigations with high depth at C+J+F)	204.8	10.0	54.1	25.4	43.01	2.94	4.85	38.10
LSD (P = 0.05)	NS	NS	NS	2.1	1.56	0.29	NS	NS
Nutrient Levels								
50% NPK + FYM 15t/ha	186.6	9.8	53.0	25.7	44.28	2.62	4.06	37.37
75% NPK	196.9	9.9	53.3	25.9	44.52	2.87	4.63	37.58
75% NPK + FYM15t/ha	207.1	10.0	54.8	26.4	44.56	2.99	4.71	38.81
100% NPK (120:60:40) control 38.88		209.3	10.1	55.8	26.6	44.67	3.36	5.68
125% NPK	225.6	10.3	57.8	27.6	45.08	3.66	6.17	39.19
LSD (P = 0.05)	28.1	0.33	3.4	1.2	0.96	0.31	0.50	NS

Source: Anonymous, 2001- 2011. Annual Reports. ICAR-Research Complex for Eastern Region, Patna.

Establishment of wheat under excess soil moisture conditions

Germination and establishment of wheat varieties namely HUW 234, C-306, K-8027, KUNDAN, and UP-262 were tested at two moisture regimes i.e. 30% and saturated conditions and three sowing depths i.e. surface seeding, 2.5 cm, and 5 cm. Based on 3 years of experimentation, tillage (3.70 t/ha) over conventional sowing (3.23 t/ha) while yield under raised bed and conventional sowing were at par. Mean water saving under zero tillage and raised bed was 11.26 and 64.9 per cent, respectively (Anonymous, 2001-2011 and Singh et al., 2011).

Crop Diversification

Crop diversification is one of the major components of diversification in agriculture. Crop diversification may be adopted as a strategy for profit maximization through reaping the gains of complementary and supplementary relationships or in equating substitution and price ratios for competitive products (Singh *et al.*, 2012a). It also acts as a powerful tool in minimization of risk in farming (Singh *et al.*, 2011). These considerations make a strong case for farm/crop diversification in India. Crop diversification is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops. Crop diversification has been recognized as an effective strategy for achieving the objectives of food security, nutrition security, income growth, poverty alleviation, employment generation, and judicious use of land and water resources, sustainable agricultural development and environmental improvement. The ability of the region to diversify the cropping pattern for attaining various goals depends on the opportunities available for diversification, the need for diversification and responsiveness of the farmers to these needs and opportunities. The opportunities for crop diversification emerge from technological breakthroughs, changes in demand pattern, development of irrigation, availability of marketing infrastructure and new trade arrangements. The necessity for crop diversification arise on account of the need for (i) reducing risks associated with yield, market and prices (ii) arresting the degradation of natural resources and the environment and (iii) attaining national goals like employment generation, self-reliance in critical crop products and for earning foreign exchange.

Crop diversification by introduction of alternate production system

In the canal command area**,** wheat crop was evaluated against other diversified winter crops by introduction of QPM + potato on raised bed, sugarcane + vegetable and maize + vegetable on level lands where there was no risk of water submergence due to seepage from canal systems. Yield of potato sown on raised beds varied in the range of 22.50 to 38.00 t/ha as compared to 15.20 to 19.20 t/ha under farmers' traditional practice. An extra early short duration Pigeon Pea (ICPL 88039) was introduced during *kharif* yielding 1.0 - 1.2 t/ha grain yield for diversification and intensification of crop. Another crop was taken in *rabi* season after harvest of pigeon pea.

Crop intensification by introduction of mungbean after rice – wheat

With the Introduction of summer mung bean (cv. Vishal) of 65 days duration as para crop before the harvest of wheat to increase the cropping intensity and income besides soil fertility built up, the harvest of mung bean was recorded as 0.80 t/ha (Kumar *et al.,* 2014*).*

Pre-rabi pigeon pea based cropping systems

Results revealed that mean yield of pre-rabi pigeon pea varied from 0.8 t/ha to 1.7 t/ha under different cropping sequences. Pigeon pea yield equivalence computed for 12 cropping sequences (treatments) showed highest values for wheat - elephant yam + black gram system (7.8 t /ha) followed by tobacco-maize - dhaincha (GM) system (7.1 t/ha). The highest net return was obtained in wheat - elephant yam + black gram (Rs. 83288/ha) followed by tobacco-summer maize - dhaincha (Rs.76747/ha). The highest benefit cost ratio was recorded under mustard - green gram - black gram (1.4) followed by tobacco - maize - dhaincha (GM) and wheat - elephant yam + black gram system (Singh *et al.*, 2011).

Winter maize based diversified cropping systems

Yield of winter maize varied from 2.3 to 5.2 t/ha under winter maize based cropping system. Winter maize yield equivalence computed for 15 treatments showed highest value for tobacco-summer maize - dhaincha (GM) system followed by maize + potato - green gram- sesame, maize + potato - black gram + elephant yam, and maize + potato - green chilies, respectively. It was also observed that where highly priced tobacco, sesame, potato, green chilies, ladies finger and elephant yam were taken in the crop sequences, the equivalent yield was higher than the other treatments. The highest net return was observed (Rs. 71113/ha) from tobacco - summer maize - dhaincha (GM), followed by Rs. 69721/ha under maize + potato - green gram - sesame, Rs. 63477/ha under maize + musukdana and Rs. 61122/ha under maize + potato - green chillies. The benefit cost ratio was highest (5.4) under winter maize intercropping with musukdana followed by 3.5 under maize + ashwagandha, 2.7 under maize + lemongrass, 2.2 under maize + *Mentha arvensis* and maize + pipli, respectively.

Crop Production Strategies to Address Climate Change

Grain yield of any crop appeared highly dependent on environmental conditions during the period between floral initiation and the beginning of the grain filling stage, when the number of pods per plant and grains per pod are defined. Reproductive development is extremely vulnerable to drought stress, mainly because it involves several processes that are highly sensitive to changes in plant water status. Plants should not become so water-stressed that flower or pod abortion occurs or pod-filling is impeded. Plants grown on different dates are exposed to different solar radiation and temperature during the season and this may influence the efficiency of conversion of radiation to dry matter indicated that micronutrients treatment strengthened the physiological sink in young leaves and economic yield (Singh *et al.,* 2012b).

Crop and resource management for sustainable future cereal based systems

Under Cereal Systems Initiative for South Asia (CSISA), Platform Research is being conducted at Patna for strategic experimental research for future cereal systems with focus on rice-wheat system, its intensification and future diversification for high cereal production with Sustainable Natural Resource Management. Broad Technical Programme/Activities are: (i) Participatory adaptation of new crop and resource management technologies for Conservation Agriculture Systems (ii) New generation of resource-efficient, high-yielding cereal systems and (iii) Operating in technology delivery hubs and other selected areas and interactions with breeding programs. Four Scenarios of cropping with different residue crop health and nutrient management practices has been sown in three replications having large plot size (1,900 m^2 each). Among the different scenarios grain yield of wheat under conservation agriculture (Scenario 3: zero tillage and keeping one third residue of the previous crop rice) was 40 per cent higher than the conventional practice by farmers (Scenario 1). The conventional practice was determined by benchmark survey of 30 farmers in the vicinity of the experimental area within 25-30 km. Higher grain yield was also reflected in higher yield attributing characteristics of wheat in scenario 3. Under future cereal system (Scenario 4) potato and maize intercropping was considered for intensification and diversification (Table 4). In these plots 18.2 t/ ha of potato and 6.8 t/ ha of maize yield was obtained. The cost of different components for wheat production calculated and it was observed that net incomes were 233 and 444 per cent higher in scenario 3 and 4 respectively as compared to scenario 1. Conservation agriculture practice could save 17 per cent irrigation water in comparison to conventional practice in scenario 1. One third crop residue of wheat was retained for cowpea and entire cowpea residue was recycled in for rice in scenario 3, by zero tillage. 18.90 Mg ha-1 of crop residue in S4 and 8.09 Mg/ha in S3 as compared to 4.96 Mg/ha in S2 was incorporated. The zero tillage rice with residue retention of previous crops in S4 and S3 were 30 and 17 per cent higher than the conventional practice in S1. 17 per cent irrigation water was saved for rice cultivation in S3 and S4 as compared to S1. Net incomes were 216 and 171 per cent higher in S4 and S3 respectively than S1 (Anonymous, 2001- 2011 and Singh and Singh 2013).

Table 4: Amount of crop residue recycled in different scenarios

Scenario	Crop residue (Mg/ ha) added in different scenarios			
	Rice in wheat/ potato + maize	**Wheat in green gram/cowpea**	**Green gram/ cowpea in rice**	**Total**
S1	Removed	Removed	fallow	-
S2	1.95	1.42	1.59	4.96
S3	2.09	2.80	3.20	8.09
S4	2.32	13.50	3.08	18.90

Source: Anonymous, 2001- 2011. Annual Reports. ICAR Research Complex for Eastern Region, Patna.

System of rice intensification (SRI) and water management

The performance of SRI under different plant geometries and water regimes was evaluated to understand the growth and parameters responsible for improvement in yield under SRI over conventional system of rice production in irrigated rice system. Plant growth, yield and yield components differed significantly under SRI. Significantly highest grain and straw yields of 7.75 and 10.6 t/ha respectively were recorded under 25x25 cm spacing and when 6 cm irrigation was applied 3 days after disappearance (DAD) of ponded water as compared to other treatments. The lowest yield 4.82 t/ha were recorded under staggered planting + 6 cm irrigation of 5 DAD, which was 60 per cent lower than the best SRI treatment. Growth and growth attributes followed the similar trend (Anonymous, 2001- 2011).

Integrated Farming System

Location specific Integrated Farming System modules for small and marginal farmers

In Eastern Indo Gangetic Region, about 85 per cent of the farmers are small and marginal but sharing only 50 per cent of the land. The average size of the holding is 0.83 ha., For such prevailing situations, there is need to integrate agriculture, horticulture, fisheries and other allied enterprises like apiculture, sericulture, mushroom cultivation, livestock etc. which holds promise for this region for improvement in the livelihood of, small and marginal farmers. The area under different components of IFS has been allocated as per need and in view of nutrient recycling within the system. In one acre model, goatry, poultry, mushroom, and vermicomposting have been integrated with the crop components. Cowpea-cauliflower-onion cropping system along with poultry + mushroom + goatry fetched the highest net income of Rs. 1, 07,193 in comparison with other cropping system in a farming system mode. In addition 1.75 tonnes of vermicompost, 5.6 tonnes of goat manure and 0.8q of poultry manure were also produced by the system which were recycled within the system thus decrease in cost of cultivation were also noted. In two acre IFS model, livestock (3 cows + 3 calves), Fisheries, Duckery, and vegetables and fruits were integrated with prevalent rice-wheat crop system. It was found that Rice-wheat + vegetables + livestock + fisheries + duckery IFS model gave the maximum return per 2 acre area (Rs. 1,80,499) with 460 man days additional employment opportunity. In addition 2.1 t of vermicompost and 27.8t of cow dung were also produced by the systems which were used within the system thereby decreasing the cost of cultivation. Among different combinations, crop (0.95 ha) + fish (0.15) + Poultry (500 no.) + Duck (35 no.) resulted in maximum sustainability index (70.6) and was followed by Crop (0.8 ha) + fish (0.15 ha) + poultry (500 no.) It was also revealed from the study that plots in which recycled manures from the system were applied resulted in build-up of organic carbon in the soil (Anonymous, 2001-2011, Singh *et al.,* 2011 and Pandey *et al.,* 2012).

Contingency agronomy for flood and drought

Boro rice for waterlogged area

In this experiment, Boro rice nursery was raised by puddled method with *Gautam* variety on 15th November 1999. In January, three varieties viz. *Gautam, Prabhat* and *RAU 1400* were taken for nursery raised under exposed method with recommended package of practices. Transplanting was done on 10th Feb. for November and 24th Feb for January raised nursery. In main field above mentioned conditions was evaluated under two water management practices viz. intermittent irrigation of 5 + 2 cm at 3 DAD during entire crop season and intermittent + continuous ponding (10 days at tillering and flowering stage) was applied for the main crop. Their performance in nursery and main field was evaluated. In another set of experiment November sown nursery grown under open field conditions with FYM was evaluated under two tillage (power tiller and tractor drawn cultivator puddling), two water management level (aforementioned) and three NPK schedules (100, 125 & 150 per cent of recommended dose). Under extreme low temperature on 06th January 2003 total seven boro rice varieties/lines were sown under polyhouse with FYM and transplanted on February 18. The summary of results of 4 years of experimentation is as follows: (1) Boro rice nursery in mid-November may be sown in open field with use of FYM @ 15 t/ha maintaining soil wet and twice spray of multi nutrient at extreme cold weather. However, the nursery grown under polyhouse is better, (2) Using polyhouse boro rice nursery may be sown in January and thus, November sowing and cold injury may be avoided,(3), Boro rice variety *Gautam* is suitable both for November and January sowing and *Prabhat* is option for January sowing under polyhouse.(3) Irrigation of boro rice with 5+ 2 cm water depth at 3 days after disappearance of the ponded water may be practiced, when natural water logging is not available.(4) Power tiller puddling is better than tractor drawn puddling (5) Yield response of boro rice is upto 150 % of the recommended dose of NPK (150: 90: 60).(6) Under extreme cold condition growing seedling of Saroj is better than Gautam in south Bihar (Kumar *et al.,* 2014 and Singh and Singh 2013).

Transplanted maize under varying age of seedlings and method of nursery raising to combat

Transplanting of maize seedling grown on raised bed, flat bed, sand culture and plastic culling, in combination with four ages of seedling i. e. 4, 5, 6 and 7 weeks were taken in to account. Low plant mortality, higher plant height, maximum leaf length, and dry matter were recorded in sand bed sown seedlings which were at par with sand culture. Five weeks old maize seedlings performed better than other aged seedlings. Highest yield (5.3 t/ha) was also recorded with sand cultured seedlings, which was at par with raised bed grown seedlings (5.2 t/ha). Five weeks old seedling has given high B: C ratio of 1.95 and 1.94, with sand cultured and raised bed grown seedling, respectively. Maximum B: C ratio (2.22) was on combination of 5 week old maize seedlings with sand culture/ bed sown. Water use efficiency was highest with raised bed grown seedling (220.0 kg/ ha/cm) over all other methods of growing seedling while, 5 weeks old seedling had sown highest WUE (238.3 kg/ha/cm). Plastic cultured seedling had performed least due to lesser dry matter accumulation /plant due to weaker seedlings at the time of transplanting. At the end of 2nd year it was observed that maize can be easily transplanted by raising its seedlings and if nursery soil is mixed with sand (2:1), resulting less damage to root and higher plant vigour and yield. However, yield of plants grown in raised bed nurseries was found at par with that grown in sand culture nurseries. Transplanting 5 week old seedling resulted in maximum grain yield with 20-28 days early maturity over direct sown maize with same yield level and fits well in the cropping system (rice-maize) (Anonymous, 2001- 2011 and Singh and Singh 2013).

CONCLUSION

Eastern Indo Gangetic Plains region is characterized with unique physiography, socio economic condition coupled with fragmented land holding. Soil and water are the basic resources of agriculture. Despite the annual rainfall being adequate across all agro-eco systems, agriculture production suffers from water stress on one hand and excess runoff and water congestion causing floods on the other hand. For the sustainable crop production apart from improved agro-technology techniques like integrated watershed management, promoting conjunctive use of surface and ground water, improving water productivity through micro-irrigation, managing flooded, flood prone and waterlogged areas and acid soils management need to be perfected. Scientific and efficient management of these resources is the core of their sustainability. Ample scope of improvement in respect of crop production is available in the region as it is endowed with natural resources. Crop diversification through new crops can also play a vital role in increasing the income of rural household. Agricultural potential assessment based agro technologies suitable for the region discussed in this article along with system approach and efficient contingency planning is the key to succeed in the climate change era with respect to agricultural productivity system, as a whole. Now focus should be on technologies for small and marginal land keeping in the view the present climate change scenario to produce economically under expected frequent outburst of abiotic and biotic stresses.

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