Journal of Agriculture and Natural Resources (2018) 1(1): 90-113
ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)

Review Article

A glimpse on post-graduate thesis researches of Agronomy Department of IAAS and prioritized future research directions

Lal Prasad Amgain*, Sudeep Marasini and Buddha BK

Tribhuvan University, Institute of Agriculture and Animal Science
Rampur Campus, Rampur, Chitwan, Nepal
*Correspondence: lalprasad@iaas.edu.np
ORCID https://orcid.org./0000-0003-2470-542X

Received: August 09; Accepted: November 27; Published: December 09.

ABSTRACT

To appraise the major research outputs of agronomic crops and cropping systems and to direct the future research priorities of Agronomy Department of post-graduate (PG) program of Institute of Agriculture and Animal Sciences (IAAS), a rigorous review was accomplished on about two decadal (2000-2018) student's thesis research works. The review revealed that the agronomic researches at IAAS from 2000 to 2012 were concentrated mostly in on-station farm of Rampur, Chitwan and found their focus on 11 food grain crops with five major themes *viz.* varietal evaluation, crop management, soil nutrient and weeds management, and crop simulation modeling. With the shifting of IAAS PG program from Rampur to Kirtipur in 2013, the major agronomic researches were found to be concentrated in on-farm stations due to transitional movement of IAAS to Agriculture and Forestry University, Nepal. A total of 115 agronomic studies were conducted on various crops, of which 92 were on cereals, 8 on legumes, oilseed and minor cereals including potato. There were records of 10 studies on rice-wheat and 3 studies on maize-based systems. The huge gaps between the potential and farmers' field yield and between the potential and research station yields for rice, maize and wheat crops suggested a great scope to raise yields of cereals by improved agronomical researches on varieties evaluation, crop and nutrient management and weed management. Simulation modeling study predicted that the varieties of rice and maize adopted at present could sustain the yields only for recent few years and needed for introduction of new climate resilient varieties, then after. Innovative and new researches on eco-region suited on-farm trails with variety identification, improved crop husbandry and soil nutrient management, improved weed and water management and on agro-meteorology, conservation agriculture, climate change adaptation and crop simulation modeling are advised as future research frontiers to uplift the productivity and reduce yield gaps of major food crops and to strengthen the academics of post-graduate research in near future.

Keywords: Agronomy department, Food crops, IAAS post-graduate thesis research, On-station and on-farm research, Yield gaps

Correct citation: Amgain, L. P., Marasini, S., & BK, B. (2018). A glimpse on post-graduate thesis researches of Agronomy Department of IAAS and prioritized future research directions. *Journal of Agriculture and Natural Resources*, *1*(1), 90-113.

INTRODUCTION

Nepal is predominantly an agricultural country and crop production is an important contributor to her national economy and food security. The importance of agriculture is borne by the facts that over 80% of the population live in rural areas and depends on agriculture for their livelihood (Joshy & Rajbhandari, 2001). Agriculture has contributed about 31 % total Gross Domestic Product (GDP) and employing about 65% of the economically active population (MoAD, 2017) and about 21% (3.2 million hectares) of the total land area of Nepal is used for cultivation and the share of principal crops in area are 45% for rice, 20% for maize, 18% for wheat, 5% for millet and 3% for potatoes followed by significant proportionate on sugarcane, jute, cotton, tea, barley, legumes, vegetables and fruits (Gauchan *et al.*, 2014). Rice, maize, wheat and potato were also the major crops prioritized by the 20 years Agricultural Perspective Plan and Agricultural Development Strategies of Nepal (APP, 1995; ABPSD, 2017; Poudel, 2013). Nevertheless, other crops, such as finger millet, groundnut, soybean, mungbean and cowpea have also been grown during the monsoon/spring season and rapeseed and mustard, buckwheat, lentil and chickpea during the winter season in terai and inner-terai regions (Amgain & Timsina, 2005). The Institute of Agriculture and Animal Science (IAAS) under Tribhuwan University (TU) is the first government agricultural institution in teaching, research and extension in Nepal. Lying in the central-terai region of Nepal, IAAS ($27^0$37' N; $84^0$25'E and 256 masl.) has focused its various on-station researches suited to the humid sub-tropical climate of the country. The IAAS central campus situated at Rampur Chitwan has started producing post-graduate students since 1999-2000. After 2013, Rampur Campus was amalgated to the new Agriculture and Forestry University (AFU) and the IAAS has shifted its full-fledged B. Sc. Ag and B. V. Sc programs to IAAS Lamjung and Paklihawa Campuses and master program at Kirtipur, Kathmandu. Consequently, Ph D programs have also been started since 2005 and about 30 students have accomplished their degrees in various allied departments of Agriculture mainly in Agri-Economics, Horticulture, Agronomy, Livestock Production and Management, Entomology and Plant Pathology. IAAS is still producing the high-level qualitative and competent agriculture manpower needed for country in various allied field of agriculture, wherein the major agronomic research works are being done in on-farm trials outside Kathmandu valley. The avenue of IAAS is the post-graduate students who have completed so many thesis works in different 13 departments including agronomy and published their dissertations as their thesis research outputs (IAAS PG Bulletin, 2011).

The compilation study of all thesis works in one place as a review article would be a great job to get a bird’s eyes view in agronomical researches, which do not only reduce the costs of further research from repeated experimentations, but also save time of researchers and institutions, help to boost the crop productivity, to direct the command of further agronomic research needs of the post-graduates program and to strengthen the academics of Agronomy Department of IAAS.

METHODOLOGY

The Institute of Agriculture and Animal Sciences (IAAS) under Tribhuvan University (TU) has been conducting various disciplinary and system research works through post-graduate students' research and publishing their findings through the M. Sc. Ag thesis dissertations for over last 17-18 years. Viewing all those and drawing valid conclusions from them is not possible to all. Almost all those thesis kept at Central Library of IAAS, Rampur Campus and PG Program Library at Kirtipur , Kathmandu from during two decade (2000-2018) were critically reviewed. Moreover, the future research priorities on different agronomical crops have also been proposed. Mean comparison of review data were calculated through Microsoft Excel and qualitative traits were analyzed in percentage as per need.

RESULTS AND DISCUSSION

Major research accomplishments of Agronomy and other various departments of IAAS

IAAS have been conducting on-station and on-farm researches since 18 years on different agronomical crops. It was found that a total of 30 Ph D and 920 master level theses have been documented. About 115 agronomic studies were conducted on various crops, of which 92 were on cereals, 8 on legumes, oilseed and minor cereals crops including potato. There were 10 studies on rice-wheat 3 studies on maize-based systems (Figure 1).

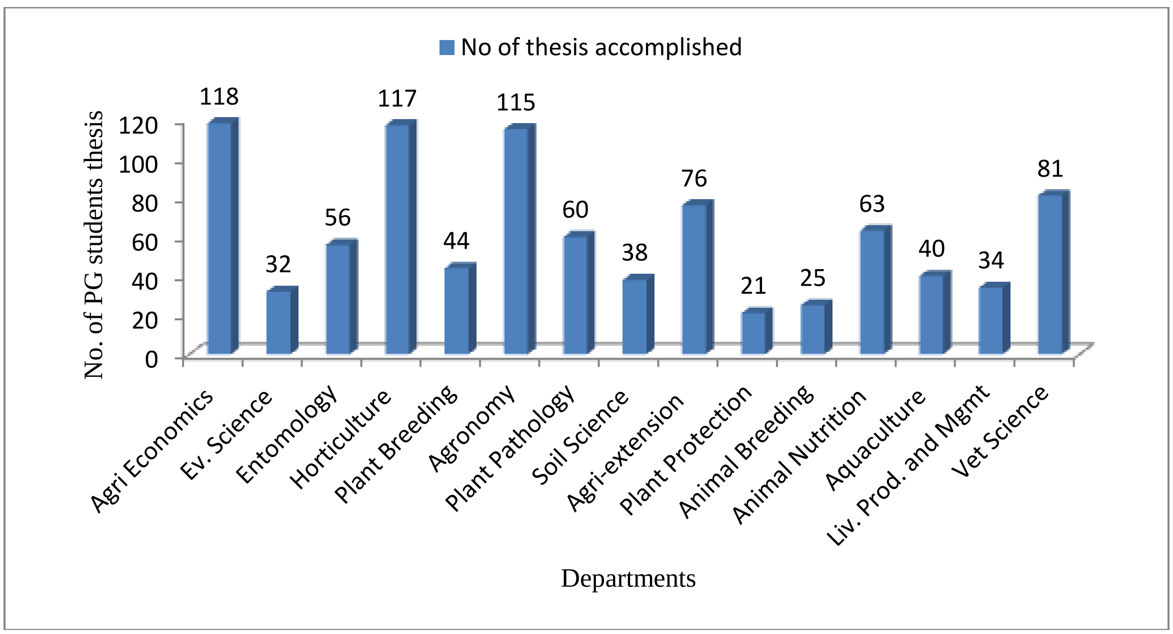

Figure 1. Number of M Sc Ag theses accomplished at IAAS Rampur, Chitwan (2000-2018)

The study was further proceeded with compilation of all thesis under different categorizes with three-way matrixes of years, crops and major themes as presented in Table 1. The rigorous findings under various management themes/ issues on various crops have been summarized in

further tables (Table 2-9) and briefly presented in texts simultaneously. In addition, the gaps between the potential (A) and the experimental station (B) yields, between experimental station and farmer's field (C) yields and between potential and farmers' field yields were calculated (Table 9) and causes of yield gaps were identified for major field crops. The causes of low productivity of major field crops were investigated and were presented.

Table 1.Three-way matrixes of total number of M Sc Ag theses of Agronomy department of IAAS (2000-2018)

	Year	Major themes					**Total**
		Varietal performance	Crop management	Soil/ nutrient management	Weed management	Crop modeling	**no. of theses**
Rice	2000-2004	-	1	2	1	-	4
	2005-2008	4*	2	5*	-	-	11
	2009-2012	4*	7*	4*	2*	1	18
	2013-2018	2	2	2	3*	1	10
Sub-total							**43**
Wheat	2000-2004	-	3*	4*	1	-	8
	2005-2008	5*	2	5*	2*	-	14
	2009-2012	-	2	1	-	-	3
	2013-2018		1			1	2
Sub-total							**27**
Maize	2000-2004	-	-	-	-	-	-
	2005-2008	2	4*	1	-	2*	9
	2009-2012	2	2	1	-	-	5
	2013-2018	1	3*	2	1	1	8
Sub-total							**22**
R-W system	2000-2004	1	3*	1	-	-	5
	2005-2008	-	1	1	-	-	2
	2013-2018			2	1		3
Sub-total							**10**
Maize-Leg system	2008-2012	-	1	-	-	-	1
	2013-2018		2				2
Sub-total							**3**
Others (Lentil, Moong bean, Black Gram, Chickpea, Buckwheat Potato etc.) (2000-2018)		2	6 (Lentil- 1, Chickpea-1, Buckwheat-2 Blackgram -1 Potato-1)	2	-	-	10
Sub-total							**10**
TOTAL							**115**

Note: * denotes theses on which researches were prioritized on more than single theme

Most researches at IAAS were concentrated on rice, wheat, maize, legumes, mustard and potato with five major themes viz. varietal performance, crop management (sowing time, planting method, plant density, spacing, seed rate, SRI), soil/nutrient management (land preparation method, tillage method, level and time of N fertilizer application), weed management (weed population, species and control methods), and crop simulation modeling. The research output further revealed that the maximum no. of researches were carried out (37%) in rice followed by wheat (23%) and maize (19%) and most of those researches were confined on crop and nutrient management themes in rice and wheat, but researches were concentrated mostly on varietal performance, crop modeling and crop management themes in maize. The research outputs on rice, wheat, maize, rice-wheat system, maize-based system and crop simulation modeling have been briefly discussed and summarized in Table 2-9.

Rice research activities of IAAS

Varietal performances

Varietal performance for hybrid versus local varieties, transplanted versus direct seeded and rainfed versus irrigated rice were evaluated by many researchers. Among ten varieties tested, direct seeded upland varieties Ghaiya -2 was found superior in Lamjung with yield (3.79 t ha^{-1}), whereas the lowest grain yield (2.26 t ha^{-1}) was recorded from Rato Kanake (Poudel, 2007). The highest straw yield was obtained from Parampuriya (9.42 t ha^{-1}) and the lowest from Bindeshowri (8.15 t ha^{-1}). In the same trial under transplanted lowland condition, rice varieties Barkhe-3017 (4.63 t ha^{-1}) was found superior, whereas Barkhe-2014 (2.90 t ha^{-1}) has shown lower performance (Poudel, 2007). In another study direct seeded rice at Chitwan showed that Hardinath-1 was most suitable than Ramdhan and Sabitri due to its early maturity (99 DAS) and higher yield (3.99 t ha^{-1}) than Ramdhan (124 DAS and 3.07 t ha^{-1}) followed by Sabitri (141 DAS and 2.76 t ha^{-1}) (Dawadi, 2012). Among hybrid and inbred varieties, hybrid Prithvi found superior with higher yield (6.38 t ha^{-1}), higher dry matter and test weight, but higher tillers (263.9) was found in Lokhnath with yield (6.14 t ha^{-1}). Hybrid variety Prithvi produced 19% higher grain yield than inbred variety Sabitri and 32% higher yield than Sunaulo Sugandha (Devkota, 2007). But, straw yield was higher from Sabitri (16.41 t ha^{-1}) and the lowest from Lokhnath (7.57 t ha^{-1}). In context of Chitwan, farmers grew released variety (80.7%) in major area under main season. Sabitri and Radha-4 were most adopted varieties (26.02% and 25.02%), respectively for medium and upland conditions of terai and inner-terai (Marahatta, 2008).

In another study of germination and seed borne disease infection, germination was found 79-98% and seed borne infection of 9-32% due to Brown spot (*Bipolaris oryzea*) for upland cultivars and 68-98% and 13-36%, respectively for lowland cultivars. The higher germination percentage and lower seed borne infection were found in local cultivars for upland rice compared to lowland rice cultivars at Sundarbazar, Lamjung (Pokhrel, 2008).

Crop management

The phenological study on transplanted rice showed that days to tillering, jointing, booting, heading, milking, dough and maturity were significantly delayed over surface seeding, but leaf area index (4.96), total dry matter production (207.62 g/0.2m^2) and nitrogen uptake (111.06 kg ha^{-1}) was significantly higher in surface seeded rice at heading stages. Higher productive tillers (187.5 m^{-2}) and grain yield (3.84 t ha^{-1}) were associated with surface seeding as compared to transplanting (165.09m^{-2}) and grain yield (3.22 t ha^{-1}), respectively. On same study it was found that surface seeding reduced 11.84% cost of production and increase net-benefit by 26.59% than transplanting (Gurung, 2006).

Rice transplanting system, SRI on which 20 x 20 cm^2 spacing was maintained and result revealed that fewer plant population under wider spacing showed the best performance due to great availability of nutrient owing to more space per plant and also show high tillering and yield/ha (Rajbhandari, 2007). In another study on SRI, the highest grain yield was obtained from 25cm x 25cm (6.04 t/ha) and the lowest (5.37 t ha^{-1}) from 30 cm x 30 cm. There was 11.17% reduction in grain yield in 30 cm x 30 cm than 25 cm x 25 cm spacing. On same study 15 days old seedling was superior than 22 and 29 days which yielded 6.59 t ha^{-1} in comparison to 29 days old seedling (4.42 t ha^{-1}) and yield reduction was 32.96% (Karki, 2008). Dawadi (2012) done a study on sowing date for rainy season rice and found that June 13 sowing rice produced significantly higher plant height, no. of tiller m^{-2}, leaves tiller^{-1}, LAI, total dry matter and heat-use efficiency with lower sterility, resulting higher grain yield (3.84 t ha^{-1}).

Study on nursery management showed that younger seedling from lower density fertilized nursery produced higher grain yield (6.96 t ha^{-1}), whereas, older seedling from higher density unfertilized nursery produced the lowest grain yield (5.74 t ha^{-1}). It was also marked that seedlings from higher density (600 g m^{-2}) has recorded low keeping quality before transplanting (Subedi, 2011).

Seedling transplanted at 15 days age resulted in longer panicle length (23.57 cm), lower tiller mortality, maximum LAI (4.03), higher flag leaf (0.455), less sterility (13.67%), higher test weight (17.06 g) and ultimately higher grain yield (3.48 t ha^{-1}) and straw yield (5.00 t ha^{-1}) than 25 days old seedling (Subedi, 2011). On the study of method of crop establishment, transplanted SRI (TPR/ SRI) matured significantly earlier (129.2 days), followed by direct seeded rice (126.8 days). These were 10 and 6 days earlier in maturity than transplanted (TPR) rice (132.9 days). Also TPR/SRI method produced significantly higher grain yield (6.95 t ha^{-1}) as compared to DS rice (6.2 t ha^{-1}) and those values were found to be 51% and 48% higher, respectively than that of TPR (4.18 t ha^{-1}). It was also found that TPR/ SRI method saved 29% and DS/SRI saved 20% irrigation water compared to TPR, but total water requirement was less in DS/SRI (13,600 m^3 ha^{-1}), which was at par with TPR/ SRI (13,630 m^3 ha^{-1}) (Dhital, 2012).

Soil management

General work on doses and time of nitrogen application was accomplished by Adhikari (2001) and result showed that 100 kg ha^{-1} N with 3 t ha^{-1} wheat straw mulch was superior (3.93 t ha^{-1}) to other treatments, but was at par with 100 kg ha^{-1} N with 3 t ha^{-1} *Cassia tora* (3.53 t ha^{-1}). On another study, effect of nitrogen doses on growth and weed management revealed that plant height, leaves/plant, plant population m^{-2}, tillers $hill^{-1}$ and LAI were found increased with increased level of nitrogen. Lower weed density and dry weight were recorded at higher level of nitrogen and found significant at 120 kg ha^{-1} N. It was also found that average increase in grain yield by 102.2% and straw yield by 107.4% due to 120 kg ha^{-1} N over control (Acharya, 2003). In another study, LCC based nitrogen management reduced both the nitrogen dose by 10-35% and cost of production by 3.67% over recommended practice of nitrogen management (Gurung, 2006).

Nutrient management in SRI revealed that the highest average yield (5.88 t ha^{-1}) was obtained by 120 kg ha^{-1} N. However, the highest straw yield (7.03 t ha^{-1}) was obtained at 160 kg ha^{-1} N. The increment in yield was about 153, 81 and 50 % due to 120, 80 and 40 kg ha^{-1} N, respectively over control, but yield reduced by 23% at level of 160 kg ha^{-1} N compared to 120 kg ha^{-1} N (Rajbhandari, 2007).

Table 2. Major technologies tested in rice at IAAS, Rampur, Chitwan (2000-2018)

Technologies tested	Yield range (t ha^{-1})	Optimum cultural practices	Characteristics/ constrains	Sources/ references
Varietal performance		Direct seeded rice at June 13th in Chitwan condition.	Early maturity in Hardinath-1 (99 DAS).	Dawadi, 2012
i) Sabitri	2.76			
ii) Ramdhan	3.07			
iii) Hardinath-1	3.99	Under lowland condition, Ramdhan was superior in Lamjung	Local cultivars were less prone to seed borne infection (*Bipolaris oryzea*)	Pokhrel, 2008
iv) IR-55435-5	3.92			
Crop management				
i) Planting method (surface seeding)	3.84	Surface seeding with wheat straw mulch @ 4 t/ha.	Reduce 11.84 % cultivation cost, early maturity, and high N uptake than transplanted rice.	Gurung, 2006 Subedi, 2012, Sharma, 2012 Gurung, 2016
ii) SRI (Ramdhan)	6.04	25 cm x 25 cm spacing with 15 day old seedling	About 11.17 % grain yield reduced on 30 cm x 30 cm spacing and weed was major problem.	Mahato, 2017 Karki, 2014
iii) Age of seedling (25 day old)	3.484		Lower tiller mortality, less sterility, high test weight	Karki, 2008
iv) Conservation Agriculture with hybrids and Nitrogen level		Rice – mustard – Maize rotation	Increase crop yield in partially irrigated field	Subedi, 2011 Marahatta, 2017
Soil/ nutrient		100 kg N + 3 t/ha wheat	Reduced the pH of flood water.	Adhikari, 2001

management	3.93	straw.	Closer spacing, higher was unfilled grains.	
i) Masuli		In SRI, 120 kg N/ha with 20 cm x20 cm spacing in rainfed condition.		Rajbhandari, 2007
	5.88			
ii) Rampur Mansuli				
	4.41	----	Reduced nitrogen dose (10-15 %) &cultivation cost by 3.67 %	Gurung, 2006 Karn, 2012
iii) LCC based N management				
iv) SSNM (N E®R)	5.3	Variety Loknath-505 (hybrid) and Sukha-5	Higher than LCC, FFP and Government recommendation	Barai, 2017
Weed management				
Pendimethaline @ 1kg a.i ha^{-1}+ 2,4 D @1kg a.i ha^{-1}	5.1	One hand Weeding	Highest B:C ratio	Bhurer 2016 Tiwari, 2011

In another study for evaluating the effectiveness of organic manures and chemical fertilizers it was found that inorganic fertilizer was superior than other organic sources because it produced the highest yield (2.34 t ha^{-1}) and it was at par with fresh and decomposed bio-gas effluent yielding 2.189 and 2.050 t ha^{-1}grain, respectively (Parajuli, 2010). B/C ratio was also higher in fresh biogas effluent (2.28) and chemical fertilizer (2.11) than the organic compost. The nutrient management result showed that among different nutrient management practices, the highest revenue (NRs 99,133ha^{-1}) was recorded under site specific nutrient management SSNM(NE®-Rice and was 33% higher than farmer's field practice, 22% higher than government recommended dose and 20% higher than leaf color chart (Barai, 2017).

Application of wheat straw mulch at 3 t ha^{-1}with nitrogen (50 and 100 kg ha^{-1}) assisted to decrease the pH of flood water. In same study it was found that higher grain yield (3.6 t ha^{-1}) on rice was obtained under 100 kg N ha^{-1} with 3 t ha^{-1} wheat straw mulch, but was at par with combination of 100 kg N ha^{-1} and 3 t/ha *Cassia tora* mulch (3.44 t ha^{-1}). Maximum grain yield of wheat (2.86 t/ha) was obtained with conjoint use of 100 kg N and 3 t ha^{-1}wheat mulch to rice (Poudel, 2007).

Weed management

Trials on weed management was conducted over control, hoed once, butachlor @ 1.5 kg a.i./ha and @ 2 kg a.i./ha and resulted that butachlor @ 1.5 and 2 kg a.i./ ha were superior to control weed than the other practices. N uptake by weed decreased due to weed control methods and was the lowest with butachlor @ 2kg a.i/ha (Acharya, 2003). Weed management and weed control methods on SRI revealed that 3 soil aerating weeding at 14, 28 and 42 DAT was most effective method, which contributed to higher no. of effective tillers m^{-2} (282.67), panicle wt (3.92 g), no of grains panicle^{-1} (184.54), lower sterility (7.36%) and higher grain yield (6.5 t ha^{-1}) (Pandey, 2009). Different mulching materials to weed growth showed lower weed dry matter under weeding with herbicide (bispyrabic sodium) application (1.153 g m^{-2}) than wheat straw mulch (6.75 g m$^{-2)}$. Brown manuring with *Sesbania* and *Eupatorium* mulch were equally effective (Gaire, 2010). The yield loss of 41.1 kg ha^{-1} was recorded under weed density of 10 m^{-2} as compared to no weed condition. Application of *Eupatorium* mulch one day after sowing was superior in grain yield (3.5 t ha^{-1}) followed by *Sesamum* BM (2.97 t ha^{-1}) and wheat straw mulch (2.83 t ha^{-1}) over control (1.77 t ha^{-1}). In dry direct seeded rice (DDSR), among the weed control practices application of pendimethalin (1 kg a.i ha^{-1}) followed by 2,4 D (1 kg a.i ha^{-1}) at 25 and hand weeding at 45 days after sowing was found the best for obtaining higher yield and efficient weed control in Parwanipur and Hardinath Farm of NARC (Bhurer, 2016).

Wheat research activities of IAAS

Varietal performance

Drought management study on various wheat cultivars (*viz.* BL-1473, NL-297, BL-2217) tested at IAAS Agronomy Farm indicated that BL-2217 produced significantly higher biological yield (7.16 t ha^{-1}), grain yield (2.68 t ha^{-1}) and HI (36.41%) due to their lower floret sterility, more numbers of grains per spike and higher HI, both under surface seeding and conventional tillage (Yadav, 2002; Sapkota, 2007). Among 10 tested wheat cultivars RR 21, UP 262, BL-1473,

Nepal 297, Bhrikuti, Rohini, BL-1887, BL-1022, Achyut and BL-2217, variety BL-2217 produced the highest grain yield (4.27 t ha^{-1}) followed by BL-1887 (4.11 t ha^{-1}) and Rohini (4.09 t ha^{-1}) on December 1st planting with fungicide spray (Dhakal, 2007).

Table 3. Major technologies tested in wheat at IAAS, Rampur, Chitwan (2000-2018)

Technologies tested	Yield range (t ha^{-1})	Optimum cultural practices	Characteristics/ Constant	Source/ References
Varietal performance i) BL-2217	4.27	Cultivars sown on two dates Dec.1st and 31st with fungicides.	Among 10 varieties studied, timely sowing with fungicides increases productivity.	Dhakal, 2007
ii) BL-2800	3.91	25 cm row spacing in North-South direction.	--------------	Pandey, 2008
iii) Gautam	5.17	Sown on Nov. 20th. Late sown irrigated condition.	3 varieties with 4 sowing dates. Higher plant population (294/m^2) at 60 DAS at Nov.20th.	Acharya, 2008
iv) BL-2217	2.67		Lower floret sterility, more no. of grain/spike and HI.	Sapkota, 2007
Crop management i) Irrigation	3.0	Three irrigations at CRI, booting, and milking stage was at par with at CRI and booting.	Dew cannot fulfill the water requirement of Wheat.	Panthi, 2011
ii) Row-spacing and direction.	3.91	25 cm row spacing in North-south direction.	Humid sub-tropical condition.	Pandey, 2008
iii) sowing dates (Nov.20th)	5.17	Variety Gautam was superior.	Loamy sand with PH 5.8 and highly organic matter (2.1 %).	Acharya, 2008
iv) Sowing date (Nov 15 and	3.39	Variety WK-1204 under zero tillage	Higher yield than Annapurna-4	Marasini, 2016 Dhakal, 2013

ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)

Nov 30)	3.56			
Nutrient management		Late sown condition	Grain yield declining beyond	Sapkota, 2007
i) 90 kg N/ha	3.09		90 kg N/ha, due to decrease	Kuinkel, 2004
		½ N at sprouting and ½	in test weight.	Tripathi, 2006
ii) time of N application	3.36	at CRI in zero tillage	Clay loam soil	
Weed management		Hand weeding was at	High incidence of weed of	Sharma, 2004
Isoproturon @1 kg ai/ha		par with chemical	family	

The grain yield was significantly higher in fungicide protected plot than non-protected plots. In another study, the maximum grain yield (3.91 t ha^{-1}) was obtained from BL-2800 followed by Gautam (2.97 t ha^{-1}) at 25 cm row spacing in north-south direction (Pandey, 2008). Similarly, wheat variety BL-2800 produced higher grain yield (4.71 t ha^{-1}) followed by Gautam and the lowest in BL-1473 (4.01 t ha^{-1}) with 120 kg N ha^{-1} (Manandhar, 2008). The another varietal and planting date experiment revealed that wheat variety Gautam planted on November 20 produced higher yield of 5.17 t ha^{-1} followed by BL-1473 (3.83 t ha^{-1}) (Acharya, 2008).

Crop management

Different tillage system affected growth characters, nitrogen uptake, yield and yields attributes of wheat and were found superior under conventional tillage system whereas mulching reduced the weed infestation (weed density and dry mass). In the same study the grain yield was increased by 22% in conventional tillage system over zero tillage and 35% with mulching (Yadav, 2002). For late-sown wheat, seed rate and irrigation resulted significant effect on different yield attributes and found that effective tillers per square meter was significantly higher under 200 kg ha^{-1} of seed rate, while other yield attributes were significantly higher under 100 kg ha^{-1} However, the higher grain yield (3.37 t ha^{-1}) was found with moderate seed rate of 150 kg ha^{-1} (Shrivastava, 2003). The seeding method significantly affected growth, yield attributing characters and yield of wheat. In surface seeding, the values of all yield attributes were lower in the first year, but from second year onward they were gradually increased and showed significantly higher result than the conventional seeding in third year (Tripathi, 2006).

Yield attributes like plant population, number of tillers and leaves, and grain yield were higher when planted on 20th November in Gautam than Bhrikuti and NL-297 (Acharya, 2008). In the spacing trial conducted by Pandey (2008), it was showed that row spacing of 25 cm in north-south direction was found more economic in the humid sub-tropical condition of Chitwan. Irrigation was considered the most important factor affecting wheat yield. In another study of similar nature the higher net returns was obtained from two irrigation given at CRI and booting stages (Panthi, 2011).

Soil management

The nutrient management in wheat at Rampur suggested the differences in the time of nitrogen application and it has affected phenology, growth and yield and yield attributing characters of wheat. Tthe research results further showed the significant different for the treatment half dose of nitrogen applied at sowing or 10 days after sowing and remaining at CRI stage, which has given 13% more grain yield (Yadav, 2002). The level of nitrogen application affected the phenology, growth, yield attributing characters and yield of wheat (Shrivastava, 2003). In next study,

significantly higher grain yield (3.09 t ha^{-1}), straw yield (5.39 t ha^{-1}) and biological yield (8.49 t ha^{-1}) were observed with the application of 90 kg N ha^{-1} and the response of grain yield on nitrogen was found to be quadratic *i.e.* grain yield started declining beyond 90 kg ha^{-1} due to decrease in test weight (Sapkota, 2007). There was records of 13.69% grain yield decrease in wheat for 120 kg ha^{-1} than 80 kg ha^{-1}.

Weed management

Weed management practices had no significant effect on nitrogen utilization efficiency, whereas significant increase in agronomic efficiency with Isoproturon @ 1 kg a.i/ha. The hand weeding was statistically at par with chemical weed control measures (Sharma, 2004).

Rice-wheat system research activities of IAAS

Among various trails conducted at IAAS, Chitwan on rice-wheat system (Table 4 and 5), it was found that wheat varieties suitable for rice- wheat system for surface seeding method was NL-297, which produced higher grain yield (3.74 t ha^{-1}) followed by Bhrikuti, Rohini, Triveni, UP262, NL769, NL783, NL252, Vaskar and Siddhartha (Yadav, 2002). Under Conservation agriculture and conventional practice, the grain yield of rice was higher in conventional practices (4.31 t ha^{-1}) than CA (4.06 t ha^{-1}), but the grain yield of wheat was significantly higher under CA (2.61 t ha^{-1}) than conventional practices (2.43 t ha^{-1}) (Paudel, 2013).

Table 4. Grain yield, residue yield and aboveground plant nitrogen returned to soil by different spring season crops under different pure and intercrops at IAAS, Rampur (Devkota, 2002)

Treatments	Grain yield (kg ha^{-1})		Residue yield (kg ha^{-1})		Aboveground plant N returned to soil (kg ha^{-1})	
	2000	2001	2000	2001	2000	2001
Blackgram	318	211.25	3935	3221.05	82.635	67.65
Mungbean	612	391.3	2152	1886.43	46.32	40.51
Cowpea	714	362.4	2671	3090.56	58.89	67.78
Maize	2566	2906	3217	3846.87	19.14	24.8
Maize with Blackgram	2486	2875.6	2402	3511.9	14.29	20.41
Blackgram with maize	129	185	1605	1519.37	33.7	31
Fallow	-	-	2866	2660.2	25.08	26.35

Marahatta (2017) conducted the experiment on rice- mustard-maize cropping system under conservation and conventional agriculture under different Nitrogen levels 0, 60, 120 and 180 kg ha^{-1} for rice; 0, 80, 160 and 240 kg ha^{-1} for maize; and 0, 30, 60 and 90 kg ha^{-1} for mustard and found that system productivity was non-significant in CA and conventional agriculture in 2 years, but hybrid produced significantly higher yield than high yielding varieties and increasing nitrogen levels increased the system yield significantly up to third level of nitrogen during both years. Under SSNM Nitrogen application rate N rate was significantly decreased by 4.18%, P_2O_5 application by 28.37% while increased K_2O application by 80.00% and resulted in 5.93% increased in yield as compared to recommended dose of fertilizers.

Wheat cultivar Achyut produced the highest straw yield (6.03 t ha^{-1}) and NL-297 recorded the highest test weight (47.07g) in Rampur (Sapkota, 2007). The legume crops accumulated higher amount of above ground plant N than maize. Among legumes, black gram accumulated the highest dry matter (3995.0 kg ha^{-1}) and the highest aboveground plant N (82.63 kg ha^{-1}) returned to the soil. Similarly, the higher economic returns were overlooked with mungbean- rice-wheat system followed by maize + blackgram-rice-wheat system (Devkota, 2002).

Table 5. Results of various legume inclusions on the economics of rice-wheat system at IAAS, Rampur (Devkota, 2002)

Characters measured	Treatments			
	Mungbean-rice-wheat		Maize + black gram-rice-wheat	
	2000	2001	2000	2001
Gross returns (Rs ha^{-1})	79612.3	10346	-	-
Net returns (Rs ha^{-1})	-	-	44811.2	48487.8
Wheat equivalent yield (kg ha^{-1} $year^{-1}$)	8738.4	9776.7	-	-
Grain production efficiency (kg ha^{-1} day^{-1})	-	-	28.84	31.34

Maize research activities of IAAS

Varietal performance

Different varieties of maize were tested on different aspect such as cold tolerance, hybrid *vs* improved and their performances on different ecological regions. Productivity of Composite varieties (Rampur Composite, Upahar and Arun-4) of maize during spring, 2007 recorded the highest grain yield (4.62 t ha^{-1}) from Upahar which was 9.3% and 2.68% higher over Rampur Composite and Arun-4, respectively (Bhusal, 2008). Leaf area index, total dry matter, ear diameter and kernel rows/ear were significantly higher in variety Upahar which also results higher yield (Pandeya, 2008). Among cold tolerance varieties tested, hybrid Pioneer with mean yield (8.35 t ha^{-1}) was superior over Rampur Composite (5.56 t ha^{-1}) in Chitwan condition (Acharya, 2011). In another study for cold tolerance varieties namely Rajkumar, Pinacle, 30V92, 30B07, RML4 x NML2 and Rampur Composite, higher grain yield (5.64 t ha^{-1}) was produced by variety 30V92 and was statistically at par with the varieties 30-B07, Rajkumar and Pinacle. All hybrid varieties except RML4 x NML2 produced higher grain yield than Rampur Composite, the popular open pollinated variety throughout the country (Katuwal, 2012).

Crop management

Study on identifying optimum plant density in crop field for spring season maize, result showed that plant population of 7.41 plant m^{-2} gave the highest yield of 4.55 t ha^{-1} which was 6.5%, 11.3 % and 21.1% higher over plant density of 6.35, 5.56 and 4.76 plant m^{-2}, respectively. Regression analysis further revealed that each higher level density added 0.256 t ha^{-1}grain yield on an

average (Pandeya, 2008). In another study, yield attributes namely no. of cobs $plant^{-1}$, cob length, cob diameter, number of grain rows cob^{-1} and test weight increased with decreasing plant population levels and barren plant ha^{-1}. Increasing levels of plant population resulted the highest grain yield under plant population 6.66 plant m^{-2} at spacing of 60 cm x 25cm (Shrestha, 2007). The planting date for winter maize showed that Oct.11th and Oct. 31th were the appropriate date of sowing at foot hill and terai conditions, respectively. Reduction in grain yield due to delay sowing of 15 days and 30 days from Oct.11th was to the extent of 17.08 and 29.98 %, respectively at Chitwan condition. Reduction of grain yields due to 10 to 20 days delay from Oct.31thwas 48.97 and 39.50%, respectively in Bara (Katuwal, 2012). Regmi (2009) from his study found that Arun-2 was suitable over Rampur Composite and Deuti and 1:3 soybean row ratio was most appropriate than 1:2 and 1:1 row combinations, respectively. Dahal (2013) on spring maize under no tillage condition reported that the maize grain yield increased by 23.19% over conventional tillage, residue retained by 39.84% over residue removed.

Research dose of fertilizer (180:115:160 kg NPK ha^{-1}) increased yield by 132.60% over farmer's dose (70: 30: 50 NPK ha^{-1}). Also B:C ratio was increased in no tillage by 35.80% over conventional tillage, residue retained by 25.19% over residue removed, research dose of fertilizer by 56.95% over farmer dose of fertilizer along with herbicide use by 31.98% over manual weeding.

Table 6. Major technologies in maize at IAAS, Rampur, Chitwan (2000-2018)

Technology tested	Yield range (t ha^{-1})	Optimum cultural practices	Characteristics/constrains	Reference/ source
Varietal performance			High LAI, total dry matter, ear diameter, kernel row/ear.	Pandeya, 2008
i) Upahar	4.26	Spring sown,		
ii) Rampur composite	3.80			
iii) Arun-4	3.07	Maize:soyabean intercropping in 1:3 ratio	Higher LER (1.59) and yield equivalent to 8.57 t/ha.	Regmi, 2009
iv) Arun-2	1.62			
Crop management		Sandy silt loam, p^H5.13, N-0.123%, P-77.56 kg/ha, organic matter content (1.85%).	Soil was Potassium deficit	Shrestha, 2007 Karki,2017 Dawadi, 2009 Yadav, 2016 Dhakal, 2013
i) Planting density (6.66 plants/m^2) and spacing (60 x 25) cm^2.	5.113			
ii) Sowing date (Oct. 11th)	5.743	Variety 30B07 is suitable	Resistance to sterility	Khatri, 2014 Katuwal, 2012 Dhakal, 2013

				Shrestha, 2013
Nutrient management i) 240 kg N/ha	7.74	Irrigated condition	Rampur Composite yield did not increase significantly onward 120 kg N/ha and for Pioneer 180 kg N/ha.	Acharya, 2011 Ghimire, 2013 Kaduwal, 2014 Pandey, 2012
Weed management	6.5	Winter maize with conservation tillage	New herbicide molecules of tank mixed and pre and post emergence are effective	Shrivastav. 2013

Soil management

Economic optimum dose of Nitrogen fertilizer in irrigated condition of maize showed that increasing nitrogen levels from 0-240 kg ha^{-1} increased the grain yield, but declined then onwards. Increasing nitrogen level increased the number of ears harvested per unit area, grain rows/ear, kernels, no. ear^{-1} and test weight. The highest mean grain yield (9.74 ton ha^{-1}) was obtained from 240 N kg ha^{-1} applied plot which was at par with 180 kg N ha^{-1} (9.45 t ha^{-1}) and 300 kg N ha^{-1} (Acharya, 2011), but higher than 0 kg N ha $^{-1}$ (1.73 t ha^{-1}), 160 kg N ha^{-1} (3.96 t ha^{-1}) and 120 kg N ha $^{-1}$ (7.62 t ha^{-1}). The percent increment in yield due to application of 50, 100, 150 and 200 kg N ha^{-1} was to the extent of 62.11, 104.74, 135.68 and 154.74 %, respectively over control (0 kg N ha^{-1}).

Crop simulation modeling and climate change research activities in major cereals

The simulation studies done for the rice and maize crops in the sub-tropical environment of IAAS premise by the use of DSSAT- CSM-CERES crop model indicated that hybrids were high yielders, but found to be more sensitive to various scenarios of climate change and affected adversely (Table 7 and 8 and Figure 2). The effect of global climate change was also seen in Nepal and the study being done on this line clearly indicated that the increased temperature and concentration of CO_2 would be most harmful to both rice and maize crops to reduce their yield because of shortening crop duration and other effects on the formation of net assimilates (Sapkota, 2007; Bhusal, 2008; Lamsal, 2009; Shrestha, 2013).

Hence, the adoptive measures should be suggested to minimize this yield gaps in major field crops. Similar result was noticed in wheat when Marasini (2016) has conducted a simulation trial in Lumle, Pokahara.

Table 7. Simulation of wheat yield with changing climatic scenarios at Lumle, Pokhara (Marasini, 2016)

Climate change scenarios					Crop yield and biology		
Min temp (°C)	Max T (°C)	CO_2 conc. (ppm)	Solar radiation (MJ/m²/day)	Crop varieties	Growth duration (days)	Simulated yield (kg ha^{-1})	% yield change
+4	+ 4	+20	+1	Farmer's Local	113	2169	71
				WK-1204	121	761	28
				Annapurna-4	123	481	22
				Gautam	118	592	32
+4	+ 4	+20	-1	Farmer's Local	113	2008	66
				WK-1204	121	678	25
				Annapurna-4	123	472	21
				Gautam	118	507	28
-4	- 4	+20	+1	Farmer's Local	182	3914	128
				WK-1204	188	4423	161
				Annapurna-4	196	3874	179
				Gautam	187	4036	219
-4	-4	+20	-1	Farmer's Local	182	3771	123
				WK-1204	188	3944	144
				Annapurna-4	196	3530	163
				Gautam	187	3672	199

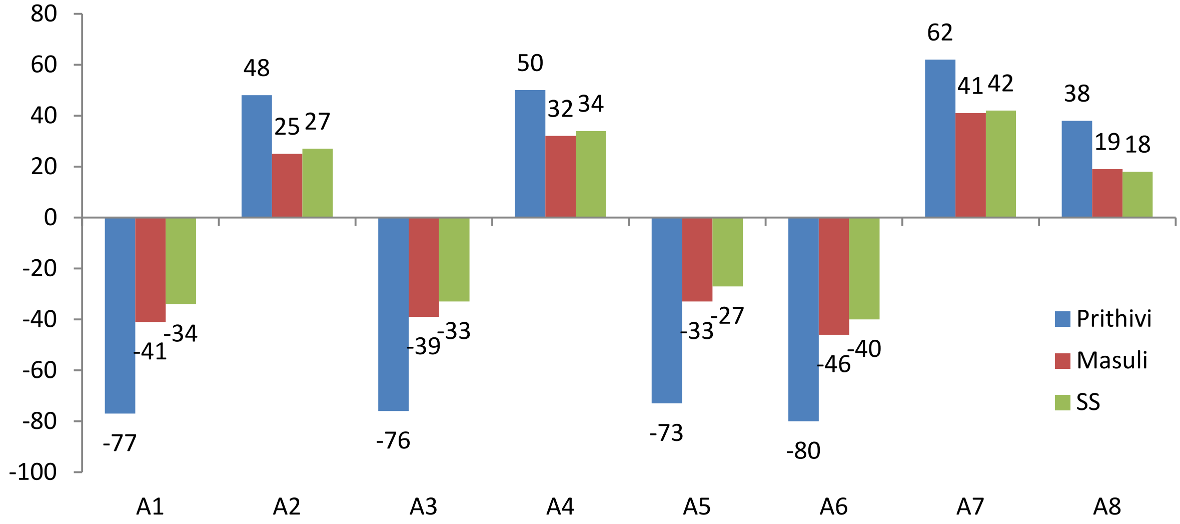

Figure 2. Percentage change in grain yield of rice with respect to various climatic scenarios at IAAS (A1-A8 are the scenarios of weather/climate change as given by IPCC (2007) Source: Lamsal (2009)

ISSN: 2661-6270 (Print), ISSN: 2661-6289 (Online)

Table 8. Simulation of maize yield with changing climatic scenarios at IAAS Rampur (Bhusal, 2008)

Climate change scenarios					Crop yield and biology		
Min temp (°C)	Max T (°C)	CO_2 conc. (ppm)	Solar radiation ($MJ/m^2/day$)	Crop varieties	Growth duration (days)	Simulated yield (kg/ha)	% yield change
Standard model parameters				R Composite	109	4357	-
				Upahar	112	4868	-
				Arun-4	100	3841	-
+4	+4	0	0	R Composite	96	3809	-13.5
				Upahar	98	3624	-24
				Arun-4	88	3068	-25
+4	+4	+20	-1	R Composite	96	3373	-22
				Upahar	98	3300	-34
				Arun-4	88	2843	-26
-4	-4	+20	+1	R Composite	128	6491	+49
				Upahar	130	6103	+25
				Arun-4	120	5525	+44

Research achievements in minor cereals, potato, legumes and oilseed crops

Buckwheat is gaining momentum during winter in terai and the result conducted at Rupandehi district revealed that effect of October sowing and 40 kg ha^{-1} seed rate was effective in higher yield and profitability of buckwheat (Timalsina, 2012). Response to potash and mulching level in potato chips was outstanding result found in Nawalparasi (Dhakal, 2012). Climate change adaptation in chickpea under late planted condition was recorded by FYM and straw mulching in Madi, Chitwan (Dhakal, 2017).

Micro-nutrient (Bo) management under lowland condition of mid-hills in Kathmandu was found satisfactory in enhancing lentil yield (Panthi, 2017) Phosphorus management in blackgram (Pathak, 2012) and soil fertility and seedling date in management in cowpea was the legume diversification study in Nepalgunj and Rampur, respectively (Sah, 2008). The application of micro-nutrients (Mo, B, Zn) and *Rhizobium* inoculation in mungbean was found important in managing proper nodulation and pollen tube formation (Sapkota, 2012; Subedi, 2012).

Yield gap analysis of major crops at IAAS premises Chitwan and Nutrient Expert Modeling work at Rupandehi

The cursory view of data in Table 9 indicated that the potential yields of major crops grown at IAAS station trails in Nepal were quite low. The common rice cultivar ‘Hardinath-1’ grown in Chitwan has the yield potential of 5.0 t ha^{-1}, whereas maize cultivar 'Rampur Composite' has the yield potential only up to 4.4 t ha^{-1} (NARC, 2013). Similarly, the popular wheat varieties at IAAS premises are NL-297, UP-262, BL-1473, and average potential yield for wheat variety Gautam was found 5.0 t ha^{-1} yield potential.

The gaps between potential and farmers' field yields is much larger than the other yield gaps, suggesting large scope for increase in yields in farmers' fields both through improved management and improved varieties. Since the potential yield is governed by both biotic and abiotic factors, it is often difficult to harvest the same yield either in farmers' field or in an experimental research station. The experimental station yields, identified as direct research outputs, would seem to be cost effective technologies to the farmers of IAAS campus premises.

Table 9. Yields and yield gaps (t/ha) of major field crops at IAAS premises

Crops/Cultivars	Potential yield (A)	IAAS Station yield (B)	Farmers' yield (C)	Yield gap 1 (A-B)	Yield gap 2 (B-C)	Yield gap 3 (A-C)
Rice	5.0	3.99	3.2	1.10	0.79	1.8
Wheat	5.0	4.27	3.4	0.73	0.87	1.6
Maize	4.4	4.19	3.4	0.21	0.79	1.0
Legumes	2.2	1.5	1.2	0.7	0.3	1.0
Oilseeds	2.0	1.2	1.0	0.8	0.2	1.0

The yields of rice, wheat and maize were increasing steadily in Nepal. The gaps between the potential and farmers' field yields (yield gap 3) of major crops are: 1.8 t ha^{-1} for rice, 1.0 t ha^{-1} for maize and 1.6 t ha^{-1} for wheat. For rice, the yield gap between potential and research station yields (yield gap 1) is larger than that for maize and wheat, suggesting that improved agronomical research on rice varieties and crop and soil management would be required to reduce this gap.

The gap between research station and farmers' field yields (yield gap 2) is larger for wheat than for the other two crops suggesting the farmers' management for wheat is poor and for that extension of recommended technologies and their adoption by farmers would help increase farmers' yields and reduce the gap. The results suggest that there is great scope to raise yields of all cereals in farmers' fields, more so for wheat and maize than rice.

CONCLUSION

Bridging the gaps between potential and experimental station yields, between experimental station and farmers' field yields and between potential and farmers' field yields are possible only through the rigorous scientific agricultural research.

While the research conducted so far at IAAS has certainly contributed in narrowing the various gaps to some extent, it seems that such research have not contributed significantly to increase the yields of various crops in the farmers' fields because research and extension systems have not sufficiently and effectively addressed the farmers' needs or reached their fields.

A range of innovative and relevant research programs, including effective and efficient on-farm research and extension systems may be needed to substantially narrowing the yield gaps and benefit the farmers. For example, in rice, biodiversity maintenance, high quality and aromatic rice production, development of high yielding varieties and eco-region suited technology identification through crop modeling and agro meteorological studies should be given emphasis. Variety identification, weed management and up-scaling for uplands. Ecological zone classification and technology identification through modeling and hybrid seed production could be some priority areas for maize researches.

Search for the cost- and energy-efficient land preparation options is major challenge for wheat in the rice-wheat system. Integrated nutrient management (INM) techniques should be emphasized in cropping system research. The nutrient uptake and precision agriculture researches like conservation agriculture and crop diversification for value addition as like chips potato were very rare at IAAS and hence, therefore would be very beneficial to start the agronomic researches in this line. Further research funding would be required to continue and flourish the advanced agronomical research works at IAAS.

ACKNOWLEDGEMENTS

The authors are highly acknowledged to the staffs of libraries of IAAS, Rampur Campus and post-graduate program, Kirtipur for providing the records of post-graduate theses of the IAAS. The post-graduate students of IAAS, the major advisers and donors are equally thanked to conduct the various trials in Agronomy Department of IAAS.

Author Contributions

The LPA has contributed in framing the outline of the research review works and has given the ideas to out-frame the research results from the compilation of the M Sc Ag theses of the Agronomy Department of IAAS. SM, an M Sc Ag student in Agronomy at IAAS helped in compiling the research works beyond 2013 when IAAS shifted its post-graduate program from Rampur to Kathmandu. BBK. did his Under-graduate Practicum Assessment (UPA) work for the partial fulfillment of his B Sc Ag degree at IAAS Lamjung Campus under the guidance of first author of this article.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

REFERENCES

ABPSD. 2017. Statistical information on Nepalese agriculture (2015/2016). Government of Nepal, Ministry of Agricultural Development, Agri-Business Promotion and Statistics Division, Agri-statistics Section, Singha Durbar, Kathmandu Nepal.

Acharya, L. P. (2003). *Study on nitrogen use efficiency and weed management in rainfed rice*. M. Sc. Thesis (unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Acharya, N. R. (2008). *Response of wheat varieties to different sowing dates*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Acharya, S. R. (2011). *Production and economic viability of winter maize cultivars under different nitrogen levels in irrigated condition.* M. Sc. Thesis (unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Adhikari, B. B. (2001). *Nitrogen use efficiency study on rice under different level of nitrogen and mulching material*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Amgain, L. P. & Timsina, J. (2005). Major agronomical research works at the Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal: A Review. *J. Inst. Agric. Anim. Sci., 26, 1-20.*

APP. (1995). *Agricultural Perspective Plans, Main Document*. Agricultural Projects Services Centre, Kathmandu and John Mellor Associates, Inc. Washington D. C. 3-66 pp.

Barai, V. K. (2017). *Growth, productivity and profitability of inbred and hybrid rice cultivars under site specific nutrient management, in Rupandehi, Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Bhurer, K. P. (2016). *Integrated weed management for dry direct-seeded rice in rice-wheat cropping systems of Nepal.* Ph D Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Bhusal, T. N. (2008). *Simulation of growth and yield of open-pollinated varieties of maize under different levels of plant population at Chitwan condition using CSM- CERES-Maize model.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Dahal, S. (2014). *Growth, yield and economics of spring maize (Zea mays L.) in relation to tillage, residue, fertilizer and weed management in Chitwan, Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Dawadi, D. R. (2009). *Response of maize hybrids to different plants diversity and nitrogen level during winter season in inner terai environment of Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Dawadi, K. P. (2012). *Effect of sowing dates and varieties on growth and yield of direct seeded rice in Chitwan.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Devkota, B. P. (2012). *Influence of harvesting time on yield and seed quality of rice varieties under sub humid condition of Chitwan District of Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Devkota, K. (2007). *Comparative study of hybrid and inbred rice varieties with different nitrogen management practice.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Devkota, K. P. (2002). *Sustainability of Rice-Wheat Cropping System under Different Spring Season Crop's Residue Incorporation and Nitrogen Management.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Dhakal, B. (2016). *Growth productivity and climate change assessments of drought tolerant rice cultivars under different crop management practices: Simulation using CSM-CERES-*

Rice model in central terai of Nepal. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Dhakal, J. P. (2007). *Response of wheat varieties under timely and late sowing condition with and without fungicide spray at Rampur.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Dhakal, R. (2012). *Response of chips potato varieties to potash and mulching levels of tuber yield and quality of chips at Divyapuri, Nawalparasi, Nepal.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Dhakal, S. (2013). *Effect of sowing dates and seed rate on the productivity of zero tillage wheat (Triticum aestivum L.) in Chitwan*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Dhakal, S. (2013). *Performance of legume and non-legume intercropped maize cultivars in foot hills of Nepal.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Dhakal, U. (2017). *Assessing growth, productivity and profitability of late planted chickpea (Cicer arietinum L.) cultivars through climate change adaptation measures at Madi, Chitwan.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Dhital, K. (2012). *Performance of rice under system of rice intensification direct seeded and transplanted methods in Chitwan, Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Gaire, R. (2010). *Effect of mulching materials on weeds and yield of direct seeded rice*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Gauchan, D., Thapa Magar, D. B., & Gautam, S. (2014). *Marketing of hybrid rice seed in Nepal: Recent evidence from field survey.* Socio-economics and Agricultural research Policy Division (SARPOD), Nepal Agricultural Research Council, Khumaltar, Lalitpur Nepal.

Ghimire, P. (2013). *Site-specific nutrient management for rainfed maize in western mid-hills of Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Gurung, B. (2016). *Performance of different drought tolerant rice genotypes at Sundarbazar, Lamjung, Nepal.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Gurung, D. B. (2006). *Performance of rice as influenced by planting method, mulch and nitrogen management using leaf colour chart (LCC).* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

IAAS Post-graduate Bulletin. (2011). *IAAS Post-graduate Bulletin*. Tribhuvan University, Institute of Agriculture and Animal Science, Rampur Campus, Rampur, Chitwan, Nepal. PP: 1-17.

IPCC (2007). Climate Change 2007: Climate change impacts, adaptation and vulnerability. Summary for Policy Makers. Inter-Governmental Panel on Climate Change.

Joshy, D. & Rajbahandari, N. P. (2001). Agricultural development and food security in Nepal: Constraints and potential. *Advances in Agricultural Research in Nepal* (In) Paper edited by HK Manandhar, CL Shrestha, RK Shrestha and SM Pradhan. *Society of Agricultural Scientists (SAS) Nepal*: 24-29.

Kaduwal, S. (2014). *Response of hybrid maize to nitrogen levels and priming during spring season in Chitwan district*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Karki, D. B. (2014). *Response of drought tolerant rainfed rice cultivars to transplanting dates under changing climate condition in Nawalparasi, Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Karki, K. B. (2008). *Productivity and economic viability of rice under different planting pattern and age of seedling through system of rice intensification*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Karki, T. B. (2017). *Identifying pathways for improving food security outcome in two contrasting production ecologies in Nepal*. Ph D Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Karn, M. K. L. (2012). *Effect of nitrogen management and crop establishment methods on yield of rice (Oryza sativa L.).* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Katuwal, R. B. (2012). *Influence of variety and planting date on cold tolerance and yield for winter maize in Nepal.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Khatri, N. (2014). *Productivity and economic assessment of maize and soybean intercropping under various tillage and residue levels in Chitwan, Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Kuikel, J. C. (2004). *Assessment on wheat productivity under different tillage, time of nitrogen and weed management practices.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Lamsal, A. (2009). *Simulating agronomic and climate change parameter on performance of rice cultivars under graded nitrogen levels using CSM-CERES-rice model at Chitwan*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Mahato, M. (2017). *Evaluation of drought tolerant rice varieties under different planting geometry in Nawalparasi district, Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Manandhar, S. (2008). *Response of wheat cultivars to nitrogen management in Chitwan*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Marahatta, S. (2008). *Response of client oriented and formal bred practices and their adoption patterns in southern Chitwan rice varieties of different fertility management*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Marahatta, S. (2017). *Conservation agriculture and site-specific nutrient management for an intensive rice-based cropping system in western foothills of Nepal.* Ph D Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Marasini, S. (2016). *Growth, productivity and climate change assessments of wheat cultivars under staggered planting and tillage practices: simulations using CSM-CERES-Wheat* *model in mid-western hills of Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

MoAD. (2017). *Statistical information on Nepalese Agriculture*. Kathmandu, GON: Agristatistics Division.

Nepal Agricultural Research Council (NARC). (2013). National Rice Research Program. Retrieved from the National Agriculture Research Council website: http://www.narc.gov.np/org/maize_research_program.php

Pandey, B. (2012). *Tillage systems, nitrogen levels and split application of nitrogen on spring maize in, Chitwan, Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Pandey, B.P. (2008). *Growth and productivity of wheat (Triticum aestivum L.) in relation to row spacing and direction of sowing*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Pandey, S. (2009). *Effect of weed control methods on rice cultivars under the system of rice intensification*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Pandeya, C.N. (2008). *Productivity of composite cultivars of maize at different levels of plant density during spring under inner terai condition.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Panthi, D.P. (2011). *Performance of wheat as influenced by irrigation schedules and nitrogen level under late sown condition at Rampur*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Panthi, S. (2017). Productivity and profitability assessment of lentil (*Lens culinaris*) through proper tillage, phosphorous and boron fertilization under rained lowland in mid-hills of Nepal. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Parajuli, M. (2010). *Response of upland rice to different sources of organic manures*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Pathak, D. (2012*). Effect of phosphorus management on yield of different varieties of black gram (Vigna mungo L.) under Chitwan condition of Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Paudel, B. (2013). *Nitrogen management in Rice-Wheat system under conservation and conventional agriculture practices in Rampur, Chitwan*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Paudel, B. (2014). *Growth and yield response of maize and soybean intercrops at various intercropping arrangements and tillage methods*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Paudel, M. (2013). *Carbon sequestration and weed dynamics in rice-wheat system under conservation and conventional agriculture practice in Chitwan, Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Poudel, M. N. (2013). *Agronomy Journal of Nepal.* vol.3.pp:181-191.

Pokhrel, A. (2008). *Growth productivity and seed quality of upland and lowland rice cultivars*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Poudel, A. P. (2007). *Performance of different rainfed rice varieties at Sundarbazaar Lamjung*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Rajbhandari, R. (2007). *System of rice intensification under plant population and level of nitrogen.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Regmi, M. (2009). *Yield and economics of maize and soybean intercropping under Rampur condition.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Sah, M. K. (2008). *Growth and productivity of cowpea (Vigna unguiculata (L.) Walp.) varieties at different seeding dates and soil fertility management in Chitwan*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Sapkota, D. (2007). *Response of wheat varieties to different levels of nitrogen under late sown irrigated condition in Chitwan*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Sapkota, R. R. (2012). *Response of nutrients priming (Mo, B, Zn) and rhizobium inoculation in mungbean [Vigna radiata (L.) Wilczek]* .M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Sharma, J. N. (2012). *Study of transplanting dates on drought resistant rice cultivars in western terai on Nepal.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Sharma, R. (2004). *Performance of rainfed wheat of different levels of nitrogen and weed management practices*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Shrestha, J. (2007). *Growth and productivity of winter maize under different level of nitrogen and plant population.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Shrestha, N. R. (2014). *Performance of rice varieties under organic and inorganic nutrient management system in Rampur, Chitwan*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Shrestha, U. (2013). *Productivity assessment of staggered planted rainfed maize genotypes: simulation on agronomic management and climate change scenarios using CSM-CERES -maize model.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Shrivastav, N. (2013). *Weed dynamics and productivity of spring maize under different tillage and weed management methods*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Shrivastava, V.K. (2003). *Response of late-sown wheat to seed rate, levels of nitrogen and irrigation.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Subedi, H. (2012). *Productivity of mungbean [Vigna radiata (L.) Wilczek] under different level of micronutrients loading in Chitwan*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Subedi, R. (2011). *Growth and productivity of rice under different ages of seedling and nitrogen level in irrigated condition*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Subedi, R. (2012). *Impact of nursery management on growth and yield of rainfed rice in western hill of Nepal.* M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Timalsina, H. P. (2012). *Effect of sowing time and seed rate on growth and yield of buckwheat (Fagopyrum esculentum Moench) in Rupandehi, Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Tiwari, S. (2011). *Performance of unpuddled transplanted rice and weed dynamics as influenced by chemical weed control methods at Rampur, Chitwan, Nepal*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Tripathi, S. R. (2006). *Response of wheat to seeding method, mulching and nitrogen management on yield stability in Chitwan*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Yadav, B. P. (2016). *Growth and productivity of winter hybrid maize under different crop sequences and nitrogen*. Ph D Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.

Yadav, D. R. (2002). *Response of wheat to time of nitrogen application and mulch level under different tillage system*. M. Sc. Thesis (Unpublished), Department of Agronomy, IAAS, Rampur, Chitwan, Nepal.