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Adoption and Impact of Pulses Research and Development Strategies for Nepal

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Abstract

Pulses are an important component of agricultural food crops and have a vital role for achieving food and nutritional security and also serve as feed crops in many farming systems. They are generally grown under marginal land, rainfed conditions , and complex production environments. Due to different soil conditions , biotic factors and environmental stresses there is year to year high productivity variability which has resulted considerable yield gaps compared to the potentials. In fact, there are many research challenges for the sustainable pulse production. In Nepal, pulses rank fourth in terms of area after rice, maize and wheat and 5th in terms of production which occupies about 10.8% of total cultivated area. Winter pulses such as lentil, chickpea, grasspea, frenchbean and fieldpea etc share 70% and 72% respectively in terms of area and production while summer pulses such as black gram, soybean, pigeonpea, cowpea, mungbean, ricebean, common bean, cowpea, horsegram etc. share about 27.56% in area and about 26.19% in production. Overall pulses are the climate change resilient crops with diverse stress tolerance traits. Pulses have an ample opportunity for income generations and livelihood enhancement to support poor and marginal farmers. Pulses like lentil, mungbean, soybean, Phaseolus beans, pigeonpea, cowpea etc are the important crops in terms of major coverage areas and has high demand in the farm community. Being a good source of raw materials for food/feed industries of Nepal, the present production status of pulses is not sufficient to meet the national demand of consumption and support feed industries. Export and import data of pulses every year also reveals high scope and opportunity of pulses production in varied agro ecological domains of Nepal. Collaboration with international pulse research institute like ICARDA, ICRISAT, AVRDC etc in terms of research, germplasm exchange and capacity building activities has strengthened pulse research, development, dissemination and up scaling program of many improved varieties of pulses in Nepal. The estimated adoption rate of improved varieties of lentil, mungbean, cowpea phaseolus bean and pigeonpea, are 58%, 50%, 45%, 40% and 15% respectively. However there is low adoption rate of chickpea improved varieties due biotic factors (Chickpea pod borer, fusarium wilt) and unsolved national policy issues. Therefore; it is essential to give emphasis for identifying and quantifying level of adoption of pulse improved varieties and its determinants across agro-climatic regions. This paper attempts to highlight the ground status of research and development activities and future strategies of pulses in Nepal.

Keywords: Adoption; Challenges; Opportunities; Pulses; Strategies

Introduction

The world population is in increasing trend and predicted to reach ~8.9 billion by 2050 (United Nations Report 2004). Therefore, to provide food and nutritional security for increasing world population is a challenging task to all concern agriculture researchers and development workers. In the present context the certainty of climate change has posed negative impact for the successful production of pulse crop worldwide. So to combat the impact of climate change, diversifying and intensifying the exiting cropping system is utmost for massive promotion of pulses in Nepal also pulses which are considered as poor man's meat form an intregal part of human daily diet especially in several developing and some developed countries. Pulses are important food crops and has indispensable allay role for food/nutritional security, soil nitrogen economy, crop diversification/intensification and sustainable agriculture in the country. Pulses are produced on ~12-15% of global arable land and their contribution to total human dietary protein nitrogen requirement is ~30% [1]. In the end of 2014, the annual global production of pulses was about 77 million tons. The global production of pulses was about 3.5 percent of the global production in the early 1970s. Due to the slow growth rate over the last five decades, the global ratio of pulse production to cereal production has declined further, to about 2.8 percent, by the end of 2014. The global pulse production, area and yield during 2018 was ~922.78lakh tons, ~957.2lakh ha and ~964 kg ha^{-1}respectively [2]. Pulse production, area and yield during the same period was ~18.3 MT (~25% of the global production), 28.2 m ha (~35% of global area) and 650 kg ha^{-1}respectively. Further, Africa and Asia together contribute ~49 MT, i.e., 67% of the global pulse production. The annual average yield of pulses in Nepal for 10-year time period from 2008/09 to 2018/19 is 1.14Mt ha^{-1}. The yield is below average in the year 2008/09, 2009/10, 2010/11, 2011/12, 2012/13, 2013/14, 2014/15 and 2015/16 which is 0.82 Mt ha^{-1}, 0.82 Mt ha^{-1}, 0.95 Mt ha^{-1}, 0.96 Mt ha^{-1}, 1.07 Mt ha^{-1}, 1.07 Mt ha^{-1},1.08 Mt $ha^{-1}$and 1.11 Mt ha^{-1}respectively. The yield is above average in the year 2016/17, 2017/18 and 2018/19 which is 1.16 Mt ha^{-1}, 1.18 Mt $ha^{-1}$and 1.15Mtha^{-1} respectively. The percentage increase in area, production and productivity of the pulse crops in 2018/19 compared to 2009/10 is 6%, 50 %, and 41% respectively. During the fiscal year 2018/19, pulses were cultivated in a total area of 331740 ha with total production of 381987 Mt and 1.15Mt ha^{-1}yield [3]. In Nepal, most important dietary pulses include lentil, soybean, pigeonpea, chickpea, phaseolusbeans, cowpea, mungbean, black gram, horse gram, field peas, ricebean and fababean. Pulses rank fourth in terms of area after rice, maize and wheat (10.8%) of the total cultivated area. Out of which, winter pulses share about 70% in area and 72% in production while summer pulses share 27.56% in areas and about 26.19% in production. Among pulses, the winter crop lentil dominates in production (65%) as well as in area coverage (63%). Chickpea, pigeon pea, black gram, grass pea horse gram, soybean and other pulses occupied 3%, 5%, 7%, 2%, 2%, 8% and 10% in terms of total pulse area respectively whereas contributed 3%, 4%, 5%, 2%, 2%, 8% and 10% in terms of total pulse production respectively. Overall scenario indicates that among the pulse crops lentil contribute large share in area and production and has positive scope to fulfill national and international demand. Lentil development and promotion program is also addressed by Agricultural Development Strategy 2015-2035 in Nepal. The percentage increase in area, production and productivity of lentil in 2018/19 compared to 2009/10 is 11.37%, 65.5% and 48.5% respectively. Likely the annual average yield of chickpea for 10-year time period from 2009/10 to 2018/19 is 1.01Mt ha^{-1}. The percentage increase in area, production and productivity of chickpea in 2018/19 compared to 2009/10 is 11.63%, 51.09% and 35.37% respectively. The annual average yield of pigeon pea for 10-year time period from 2009/10 to 2018/19 is 0.93Mt ha^{-1}. The percentage decrease in area and production and percentage increase in productivity of pigeon pea in 2018/19 compared to 2009/10 is 21.33%, 11.31% and 12.67% respectively. The annual average yield of black gram for 10-year time period from 2009/10 to 2018/19 is 0.83Mt ha^{-1}. The percentage decrease in area and production and percentage increase in productivity of black gram in 2018/19 compared to 2009/10 is 30.45%, 25.28% and 7.34% respectively. The annual average yield of grass pea for 10 years' time period from 2009/10 to 2018/19 is1.10 Mt ha^{-1}. The percentage increase in area, production and productivity of grass pea in 2018/19 compared to 2009/10 is 32.84%, 109.5% and 58% respectively. The annual average yield of horse gram for 10 years' time period from 2009/10 to 2018/19 is 0.85Mt ha^{-1}. The percentage decrease in area and increase in production and productivity of horse gram in 2018/19 compared to 2009/10 is 23.51%, 4.01% and 35.33% respectively. The annual average yield of soybean for 10-year time period from 2009/10 to 2018/19 is 1.14Mt ha^{-1}. The percentage increase in area, production and productivity of Soybean in 2018/19 compared to 2009/10 is 5.16%, 43.21% and 36.15% respectively. The average yield of other pulses for 10-year time period from 2009/10 to 2018/19 is 1.02Mt ha^{-1}. The percentage increase in area, production and productivity of other pulses (which includes field pea, cow pea, broad bean, Phaseolus bean, Masyang, Mungi etc.) in 2018/19 compared to 2009/10 is 11.33%, 41.34% and 26.91% respectively.The results from large plot demonstrations clearly indicated that pulses production can be enhanced to the desired level if appropriate technology transfer efforts are made. Nepal has witnessed an impressive growth in pulses production during last 5 years with the good compound growth rate. The growth rate of pulse production (6.54%) during last 5 years was higher. This has also a direct effect on per capita consumption of pulses (34.84 g/capita/day which was 2 times lower than WHO recommendation i.e. 80 gm/capita/annum [4]. The overall productivity of pulses increased at an impressive rate from 762 kg ha^{-1}during 2000 to 1052 kg ha^{-1} during 2018. There was a high fluctuation in area under pulse cultivation in Nepal in the last 2 decades. The production of pulses has been continuously increasing whereas there was sharp decline in area in the year 2017/18. All these credit goes to the availability of high yielding improved varieties, source seed production, large plot demonstration through IFAD-ICARDA, bio fortification, NSAF, PMAMP projects and the technological innovations has played a major role to increase production and productivity of pulses in Nepal. Our domestic requirement of pulses is around 386900 metric tons in the present context. In order to make self-sufficiency, the pulse requirement in the country is projected 459,900 metric tons by the year 2030; at an annual growth rate of 2.2%. This will require a pragmatic change in research and developmental strategies and good policy support from the Government of Nepal. Moreover, it is an essential to focus and give emphasis for identifying and quantifying level of adoption and its determinants across agro-climatic regions. The aim of Grain Legumes Research Program, Nepal (GLRP) is to develop high yielding, disease-insect resistant/tolerant and wider adaptable improved varieties and recommend suitable technologies on different pulses to enhance the production and productivity at national level.

Why pulses are important?

Pulses so called as “Climate Change Smart Crops” or sometime it is also known as poor’s man meat because of containing multi-nutritionally enriched as they have high content of proteins, minerals like iron and zinc, vitamins, Ca, Mg. In addition to their nutritional content, there are several reasons that strongly support legume cultivation and adoption. Pulses are ideal foods for vegetarians/vegans and suitable for people with diabetes, most importantly it contains phytoestrogens chemical and free from gluten directly associated with the health prospects. It has also long shelf life. Besides pulses fixes the biological nitrogen which ameliorate the soil health and supply the nitrogen fertilizers to the companion crops. Overall pulses are the climate change resilient crops with diverse stress tolerance traits and require lesser water foot prints and have a great opportunity for income generations and enhance livelihood to support poor and marginal farmers. Pulses like lentil, mungbean, soybean, Phaseolus beans, pigeonpea, cowpea etc are the important crops in terms of major coverage areas and has high demand in the farm community for consumption and a good source of raw materials for food/feed industries of Nepal.

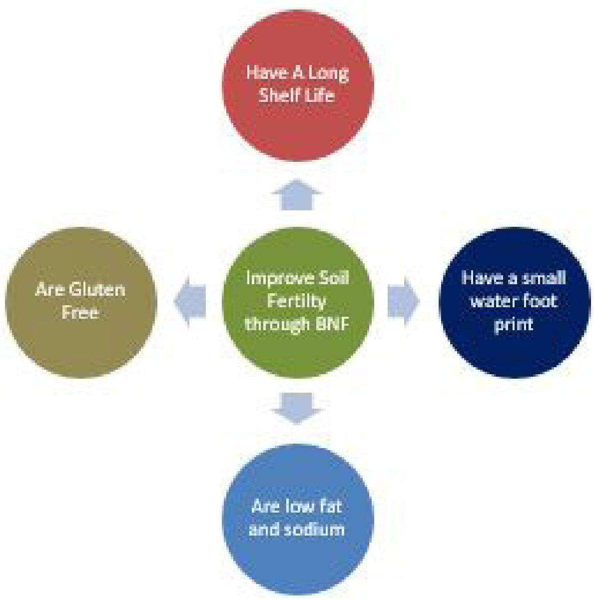

Figure 1: Importance of pulses for health security and sustainable agriculture

Possible reasons for the legumes cultivation

1. Grain legumes like lentil and soybean are known as the exportable commodities having higher export-import ratio for example in lentil is 1.3
2. Fetch higher return-cost ratio (1.6 – 2.0) as compared with cereal crops
3. Helps in cropping intensity and crop diversification
4. Pulse crops are drought tolerant and commonly grown in marginal lands
5. Pulses are more appropriate for human and animal consumption
6. Has adaptability with inter or mixed cropping system with cereals
7. Grain legumes crops stands for emergency; short duration crop
8. Agronomic management of pulses is relatively easy
9. Grain legumes are comparatively hardy crops and can be grown in low fertile soil having harsh growing conditions and face lower incidence of pests and diseases
10. Inputs (especially nitrogen fertilizer) requirement is lower as compared to cereals
11. Grain legume crops help to soil improvement through Biological Nitrogen fixation (BNF)ranges 72-372kg BNF/ha
12. Higher farm gate price (NRs 80 – 180 per kg) as compared to cereals considered as cash crops
13. Still about 0.24 million ha rice-fallow area which has ample scope for increasing pulse crops in rice based cropping system

Grain Bio-composition of Pulses

Pulses are the pertinent source of different minerals and proteins. Minerals are important for metabolic system in human body and mineral deficiencies are often associated with human diseases/disorders like cardiovascular disease (CVD), diabetes, cancer, and neurodegenerative disorders [5]. Pulses are also a good source of fiber and total dietary fiber content in legumes is about 8-27.5% [6]. Several health benefits are associated with increased consumption of dietary fiber including reduced risk of several diseases (cardiovascular disease/diabetes/cancer/obesity) and also lowers blood cholesterol levels [7, 8]. Protein Calorie Malnutrition (PCM) is a worldwide issue especially in infants, young children, pregnant mothers and age old peoples. The protein content of legumes is substantially higher (17-45.0%; Daraiet. al 2017) compared to major cereals (6.0-15.0%) [9, 10, 11]. The protein content of important grain legumes is: pigeon pea [21.7 g /100 g], chickpea [19.3 g/ 100g], lentil [25.8 g/100g], bean [23.4 g/100g], cowpea [~24.0 g/100g] and, soybean [36.5 g/100g [12]. Additionally, pulse proteins can be easily digested with high variability (60-92%) was observed in different legume crops [13]. Consumption of 100- 200 mg of legumes can meet the daily requirement of different minerals: e.g. the daily zinc requirement of 3.0mg/day for women and 4.2 mg/day for men [14] can be met by consumption of 100-200 mg of lentil, cowpea, and chickpea. Similarly, daily iron requirement (1.46 mg/day for women and 1.05 mg/day for men) can be met by consuming 100 g of most of the food legumes. Legumes are a good source of health promoting fatty acids like linoleic, linolenic, oleicand palmitic acids. Additionally, most of the legumes are also good source of carbohydrates (30-60%) [12]. The different carbohydrates in legumes include: (i) monosaccharides–glucose, fructose and ribose (ii) disaccharides– maltose and sucrose (iii) oligosaccharides– ciceritol, verbascose, stachyose, and raffinose(iv) polysaccharides – starch, cellulose and hemicellulose [15, 16, 17]. Overall pulses are absolute foods that help to develop immune power and gain energy to combat with the hot issue Covid19 pandemic.

Mandatory Crops

NARC has assigned the thirteen mandatory pulses to evaluate the phenotyping, genotyping, agronomic performances and development activities in Nepal. Based on the national priority of policy level, area coverage and production scenario, six winter season's legumes namely, Lentil (*Lens culinaris*Medikus), Chickpea (*Cicer arietinum* L.), Rajma (*Phaseolus vulgaris* L.), Grasspea (*Lathyrussativus*L.), Fababean (*Viciafaba* L.), Field pea (*Pisumsativum* L.) and seven summer season's legumes namely Blackgram (*Vigna mungo* L. Hepper), Soybean (*Glycine max* L. Merril), Pigeonpea (*Cajanuscajan*L. Millsp.), Mungbean (Vignaradiata L. Wilczek), Cowpea (*Vignaunguiculata*L. Walp), Horsegram (*Macrotylomauniflorum*L. Lam. Verdc.), Ricebean (*Vignaumbellata*L.

Ohwi and H. Ohashi) are underway in the commodity program and NARC's satellite stations as well as multi-environment testing sites. However, our entire efforts has mainly concentrated on lentil, chickpea and Rajma under winter season legumes while soybean, mungbean, cowpea under summer season legumes.

Trends of area and production of pulses

There is significantly positive change in lentil area by 9%, soybean area by 14%, grasspea area by 34% and other legumes area by 10% while negatively changes in chickpea by -19% and horsegram by -10% over the years 2009/010–2017/18 as compared to the years 2000/01–2008/09. Growth rate of area has increased in lentil by 0.8 %, soybean area by 1.3%, grass pea area by 1.1 % and others legumes by 3% over the same period. Likely there were significantly positive changes in lentil production by 38%, soybean by 41%, grasspea by 87% and other legumes by 30% while negatively changes in chickpea production by -6% and horsegram by -10% over the years 2009/010–2017/18 as compared to the years 2000/01–2008/09. Growth rate of production has increased in lentil by 4.2 %, soybean production by 3.5%, grasspea production by 5.7 % and others legumes by 5.7% over the same period. However, the Table 1 indicates that there is positive change in yield trends over the years. Explicitly measuring yield per unit area and time is therefore of increasing importance. Where multiple cropping is prevalent, yield gap analysis should target the system and its components. Here, based on the potential yielding capacity, existing yield and national average of grain legumes in Nepal, yield gap analysis was done. Potential yield (Yp) is the yield of a current cultivar "when grown in environments to which it is adapted; with nutrients and water non limiting; and with pests, diseases, weeds, lodging, and other stresses effectively controlled" [18]. Potential yield depends on location as it relates to weather. Existing yield reflects the current state of soils and climate, average skills of the farmers, and their average use of technology. National average was determined in the agricultural statistics by the Ministry of agriculture and Development. Yield gap is the difference between two levels of yield. The exploitable yield gap accounts for both the unlikely alignment of all factors required for achievement of potential or water limited yield and the economic, management and environmental constraints that preclude, for example, the use of fertilizer rate that maximize yield, when growers' aim is often a compromise between maximizing profit and minimizing risk at the whole-farm scale, rather than maximizing yield of individual crops Yield gap trends showed that there was 666 kg/ha yield gap in soybean, 744 kg/ha in lentil, 410 kg/ha in chickpea and 709 kg/ha in pigeonpea (Table 2). Yield can be increased by the government policy in mega project for transferring technologies like high yielding varieties, demonstration for the integrated nutrient management along with insect and pest management techniques which are crucial for the improvement of yield of legumes.

Area, Production and Yield	Lentil	Soybean	Chickpea	Horsegram*	Grasspea*	Others*
Harvested area (ha)						
2000/01–2008/09	184565	21896	11441	7888	6761	26842
2009/010–2017/18	201811	25034	9291	7086	9093	29455
Percentage change	9	14	-19	-10	34	10
Growth rate (%)	0.8	1.3	-1.8	-1.7	1.1	3.0
Production (t)						
2000/01–2008/09	153552	19187	9483	5541	5201	22303
2009/010–2017/18	211462	27093	8959	5626	9709	28935
Percentage change	38	41	-6	2	87	30
Growth rate (%)	4.2	3.5	0.4	0.6	5.7	5.7
Yield (kg ha^{-1})						
2000/01–2008/09	831	875	827	703	770	826
2009/010–2017/18	1043	1088	959	819	1036	981
Percentage change	26	24	16	16	35	19
Growth rate (%)	3.1	2.3	1.9	2.9	3.7	2.4

Table 1: Present Status of Grain Legumes: Change in Area and Production

Crops (var)	PY kg ha⁻¹	EY kg ha⁻¹	NA kg ha⁻¹	YG kg ha⁻¹
Soybean (8)	1800	1,117–1884	1134	666
Lentil (12)	1973	365–2112	802	1171
Chickpea (8)	1514	538–744	956	558
Pigeonpea (2)	1750	488–1700	1042	709
Cowpea (5)	900	802–1854	1360	460
Mungbean (4)	1200	589–744	1267	67
Blackgram (3)	1200	670 – 1500	840	360

Table 2: Scenario of Grain Legumes: Yield Gap

National & International Collaboration and Linkages

GLRP works with partners to enhance the production and productivity of grain legumes in Nepal. It has been working with different international institutions for germplasm exchange such as: International Center for Agricultural Research in Dry Areas (ICARDA, Morocco) for lentil, Kabuli type chickpea, grasspea and fababean; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT, India) for pigeonpea and desi type chickpea; AVRDC (World Vegetable Center, Taiwan) for mungbean and vegetable type soybean; International Institute of tropical Agriculture (IITA, Nigeria) for cowpea and soybean, and national institutions such as: Directorate of Agricultural research (DoARs), Agricultural Research Stations (ARSs) and disciplinary divisions of NARC for technologies evaluation, verification and germplasm conservation; Seed Quality Control Centre (SQCC) for variety release; provincial government and Krishi Gyan Kendras (KGKs) for technology transfer and dissemination. Similarly, the GLRP works with different NGOs, farmers' groups/cooperatives and seed company for the dissemination of technologies at farm level (Figure 2).

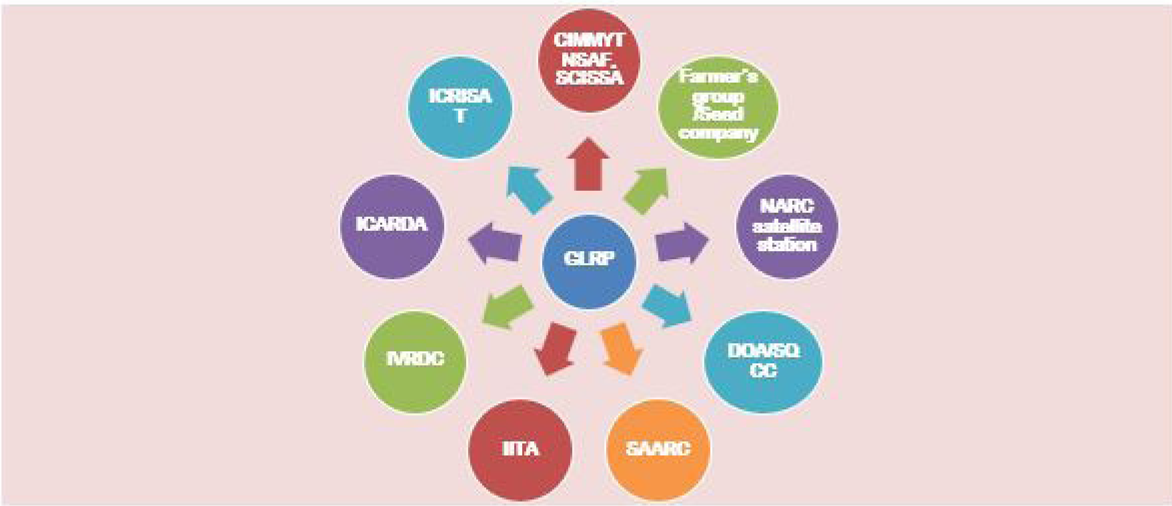

Figure 2: Linkages and collaboration with National and International stakeholders

Major issues on pulse production

- Low genetic yield potential
- Integration of conventional approaches along with the cutting edge research in area of genomics, molecular marker assisted breeding, transgenic, molecular approaches for stress management.
- Undernourished population is around 27.6% in Nepal while pulses are categorized as secondary crop; resource. Government of Nepal policy makers should be included in mega projects as mentioned in Agriculture Development Strategy
- Importing huge amount of pulses for domestic requirements (Soybean and other legumes lentils, chickpeas, Pigeonpea, Fieldpea, Cowpea, Mungbean) in the value of 45 billion Rupees
- Lower priority has given for the pulse research and development in national policy level
- Lower Seed Replacement Rate (only lentil in balance sheet Seed Replacement Rate (SRR)~6%, hiding other legumes)
- Lack of linkage with extension workers in Federal, Province & Local level which results seed stock of improved seeds
- Low attention of private sector for pulse seed production
- Agri mechanization at infant stage
- Lack of technical knowledge for machinery and equipments operation
- Ban to grow grasspea (Oxalyl diamine Propionic Acid) - which is regarded as Hardy, Climate resilient, Future food crop
- Socio-economics problems (Insufficiency quality seed, lack of seed network,rainfed crops, majority farmers treating as as an orphan Crop)
- Lack of Value addition, product diversification and food safety
- Missing pulses s in Government Game Changer project (PMAMP): It's a policy level issues
- Lack of systematized markets (Value chain) and subsidy for pulse producers
- Poor transfer of technologies to the pulse growers and extension officers
- Pulses are generally grown under marginal, rainfed, highly unstable and complex production environments resulting considerable yield gaps compared to the potentials.

Pluses: Challenges to Researchers GLRP

- Biotic stress (Diseases/ insects/ weeds)
- Abiotic stress (Drought, heat stress, water logging, cold injury)
- Shortening of crop duration (in particular winter crops in terai)
- Change in insect/ diseases dynamics
- Degradation of soil by unbalanced use of chemical fertilizers in cereal mono culture (rice, wheat, maize)
- Nutrient mining and soil acidity
- High Genotype x Environment interaction
- Reduced Seed sizes
- Huge Post-harvest loss
- Poor crop establishment
- Moisture stress in reproductive phase
- Less attention to follow the recommended technologies

current activities for varietal development and dissemination of high yielding varieties

1.Varietal Improvement (Collection, Conservation, Evaluation, Utilization, Hybridization)

2.Participatory trials in farmers' field

3.Agronomical and soil related research activities (Climate Smart Technologies)

4.Plant protection research activities

5.Source seed production(Nuclues, Breeder and Foundation seeds)

6.Dissemination of lentil varieties in large plot with National government funded project (NTIS)

7.Dissemination of bio fortified lentil varieties through Harvest plus project

8.Intensification of legume crops in rice fallow area through IFAD-ICARDA project

Figure 3: MLT Networking

Major Achievements

The output achievements are collected from diverse research activities including multi-location trialswhich is valuable to the farmers, researchers, extension workers, NGOs, students, local/province level government, policy makers, all sorts of readers and further seed companies/cooperatives aim to increasing the pulse production and productivity in the country. Nepal Agricultural Research Program (NARC) management and IARs provides strong support and guidance for the reinforcement of pulse cultivations in the cropping system and successful implementation of the projects. Similarly, supply of genetic materials, technical/financial support, training and exposure visits from the IARs like ICARDA, ICRISAT, ITTA, AVRDC, CIMMYT etc. have further assessed to strengthen the grain legumes research, capacity enhancement of the grain legume researchers and future collaboration. Pulse research will prioritize an efficient and effective delivery of quality as well as quantity research outputs in future that ultimately help to increase the production and productivity of pulses. Indeed, these consolidated achievements has been received from the untired joint efforts and dedication for the pulse research in Nepal.Diverse climate and agro domains of Nepal offer a great opportunity to grow several species of grain legumes. They are grown all-round the year as categorized into summer and winter legumes. Summer legumes includes soybean, blackgram, mungbean, cowpea, pigeon pea, horsegram, common bean, rice bean. Winter legumes includes lentil, chickpea, rajma, lathyrus, fababean, field pea (Annex ii). Till date GLRP has been released 45 different varieties of grain legumes for the diverse agro-domains. Out of which it is consisted of 23 winter legumes varieties {Lentil (14), chickpea (8) & Rajma (1)} and 22 summer legumes {Soybean (8), Pigeon pea (2), cowpea (5), mung bean (4) &Black grams (3)}.

Crop	Varieties	Domain
Lentil (14) (*Lens culinaris* Medikus subsp. *culinaris*)	Khajura Musuro-1 Khajura Musuro-2 Khajura Masuro-3 Khajura Masuro-4	Mid and Far Western terai
	Sindhur, Simrik, Sisir, Simal, Sikhar, Shital, Shradha kalo Masuro	Terai and mid hill
	MaheswarBharati, Sagun	Kathmandu Valley and river basin
	Rasuwa Kalo Masuro	Rasuwa and similar kind of environment
Chickpea (8) (*Cicer arietinum* L.)	Koseli, Kalika	Western to central terai
	Dhanush, *Trishul Radha, Sita, Avrodhi, Tara	Terai/Inner Terai
Soybean (8) (*Glycine max* L. Merril)	Hardee, Cobb	Terai
	Ransom, Seti, *Hill	Hill (Intercropping)
	Lumle -1	Mid hill
	Puja	Terai to mid hills
	Tarkari Bhatmas-1	Kathmandu Valley
Pigeonpea (2) (*Cajanuscajan* L. Millsp.)	Bageshwori	Mid westTerai
	Rampur Rahar 1	Central terai
Cowpea (5) *Vignaunguiculata*L. Walp	Aakash, Prakash, Surya, GajaleBodi, Malepatan-1	Terai and mid hills
Mungbean (4) *Vigna mungo* L. Wilczek)	Pusa Baisakhi Pratikshya, Kalyan Pratigya	Terai and foot hills
Blackgram (3) (*Vignaradiata*L. Hepper)	Kalu* Rampur Mas Khajura Mas-1	Warm valley Inner terai and mid hills ,,
Rajma(Phaseouls bean)(1)	PDR-14	Terai to high hills

(*) indicates the varieties are de-notified to due production constraints in 2008

Annex 1: List of released variety of different pulse crops for general cultivation

Research Highlights: Breeding Improvement

• **In Lentil**: High yielding genotypes HUL-57(1510 kg/ha), LN0136 (1405 kg/ha) and ILL7163 (1385 kg/ha) were found across the locations and over the years 2018-2020

• **In Low ODAP (0.1-0.2%) Grasspea**: Indian origin Ratan (1866 $kgha^{-1}$) , Bidhan-1(1323 kg/ha), Greece origin Acc # 190 (1293 $kgha^{-1}$) and Syrian origin Acc # 554(1160 $kgha^{-1}$) will be promoted to participatory trial

• **In Rajma**: High yielding genotypes PDR-14 (1862 kg ha^{-1}), Utkarsh (1698 kg ha^{-1}) and Amber (1666 kg ha^{-1}) were selected and will be proposed for releasing soon

• **In Chickpea**: Genotypes ICCV 97207 (2903 kg ha^{-1}) and KPG-59 (2689 kg ha^{-1}) were selected in terms of yield and other good traits and its promising for the coming year

• **Morphological diversity in Nepalese lentil landraces**: Quantitative traits of Shannon-Weaver diversity indices (H') observed > 0.8 & qualitative traits ranged 0.4-0.7 indicated low to medium level of intra-specific diversity in Nepalese lentil

• **Performance of Advanced Lentil Genotypes in Mid Hill of Nepal:** Best Genotypes PL-4 and ILL-7979 and will be proposed in the days to come

• **G x E bio-fortified lentil trial:** Superior lentil accessions PL-4, WBL-77, ILL-6467 and ILL-6819 were **found** across the environments and over the years (2016-2017) in terms of grain yield performances while highly stability accessions were RL-6, Simal, Shital and ILL3490.

• **Morphological and Molecular Characterization on lentil:** Morphologically distinct accessions were ILL8006, HUL-57, LG-12, PL-4, Black Masuro, RL-79, ILL-6467, ILL7723, ILL-4605, RL-49 in terms of DUS traits while in molecular level; highlypolymorphic markers PLC16, SSR124, SSR113 and SSR107 were found among the tested 40 SSR markers

• **Grain Fe and Zn Conc. Analysis:** High Fe concentration (120.82-186.57 ppm) Lentil accessions were RL-79, ILL-4605, RL-11, ILL-6819, ILL-7164 while high Zn concentration (53.75 – 87.24 ppm) lentil accessions were ILL-4605, ILL-6819, ILL-7715, RL-4, Khajura

Research Highlights: Agronomy

1. **Hydro-halo-hormonal priming techniques:** in chickpea promising lineICCV97207 was taken and by 2% solution of calcium sulphate (CaSO4) primed seed produced the highest grain yield (2.4 t ha−1) while in lentil released variety KaloMasuro was tested in seed priming experiment with a 250 ppm solution of sodium molybdate (Na2MoO4) produced the highest grain yield.

2. Increased the productivity of Rajma through proper sowing date and plant geometry: Rajma variety PDR-14 was taken. Sown on October 26 (Kartik 9) produced the 12%, 40% and 64% higher grain yield than sown on October 11, November 10 and November 25, respectively. Likely Rajma sown on October 26 with plant geometry of 30 cm × 10 cm produced the highest grain yield (2185 kg ha−1).

3. Plant establishment methods and nutrient management in lentil under upland rice-lentil system: Grain yield was not affected by tillage (ZT: 527 kg/ha, CT: 513 kg/ha), while recommended dose of fertilizer (20:40:20: N:P2O5:K2O kg/ha) + FYM 5 t/ha produced the highest grain yield of 655 kg/ha, followed by FYM @ 10 t/ha (603 kg/ha

Research Highlights: Pathology

1. Screening of lentil genotypes against stemphylium blight disease: Resistant to moderately resistant genotypes were FLIP 2014-045, ILL 7164, Sagun, RL-4, Khajura Masuro-1 , Simal ,ILL 10856

2. Lentil genotypes for disease resistance and high yielding traits in subtropical climate: Genotypes Black Masuro, ILL 3338, ILL 10265, ILL 6819, WBL 77, ILL 7164, ILL 6467 were found resistant against both Stemphylium blight and wilt disease with higher grain yield

3. Response of French Bean genotypes to root rot complex disease: Variety PDR-14 with lowest DI (3.1) possessed higher yield (1423 kg/ha)

Research Highlights: Entomology

Field Screening of Lentil Genotypes against Aphid (Aphis craccivora Koch.) in Inner Terai: On the basis of grand mean of aphid population and other yield attributing traits, the lentil genotypes ILL 9924, RL 83, ILL 38, ILL 10856, ILL 6458 and RL 67 found less susceptible with higher grain yield

Opportunities of Grain Legumes

1. Grain legumes research program is getting very good support from international research organizations For example ICARDA, Morocco/Lebanon - Segregating and advanced materials, training and exposure visits and technical backstopping (Lentil, Kabuli chickpea) while ICRISAT, India- Segregating and advanced materials, training and exposure visits, scientific exchange and technical backstopping (pigeonpea, chickpea), IITA, Nigeria- Soybean genetic material and AVRDC, Taiwan- Mungbean and soybean genetic material

2. Nepal has diverse agro-ecological environments which provides ample opportunity for the production of grain legumes

3. Still about 0.24 million ha area under rice fallows for scaling up grain legumes on those areas.

4. Peoples are simultaneously increasing the health consciousness and grain legumes are actually energy powerhouse that helps to enhance the immune power against diversity of diseases.

5. Grain legumes like lentil, soybean, Rajma has the great potential for export promotion and import substitution

6. Community level seed production and distribution networks has well established and private seed companies are blossoming and attracting towards the legumes seed production and supply system

7. Establishment and growing up community based seed production and seed companies

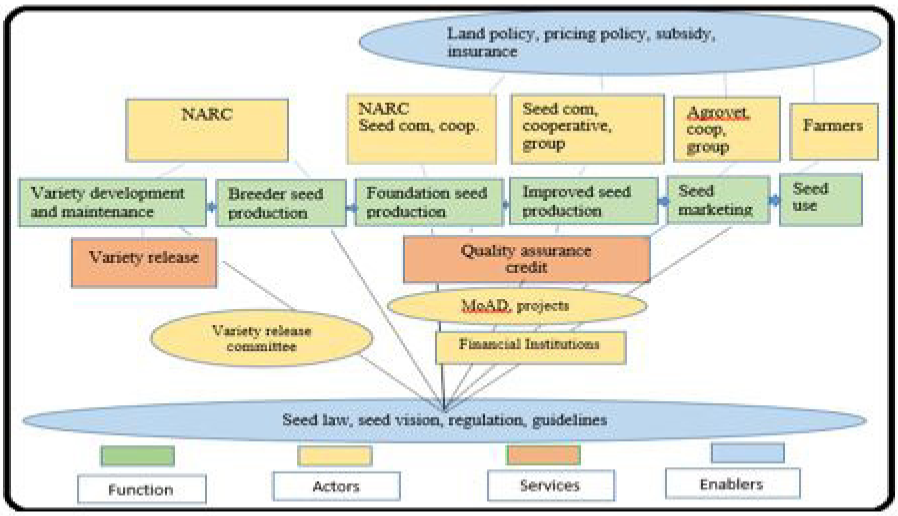

Figure 4: Pulses seed networks in pulse crop

Methodology for collecting the information sources and validation basis for adoption of pulses in Nepal

Primary information was collected from Farm and Household survey throughparticipatory rural appraisal (PRA) & Transect Walk [19, 20]. Secondary information sources were reviewed from the statistical data of Ministry of Agriculture, Developments and Cooperatives (MOAD), National Planning Reports. To validate the information sources, National News and market trends were thoroughly updated. Besides source of seed demands and supply situation data were taken from NARC's satellite stations, Grain Legumes Research Program, Seed Companies, Seed Cooperatives, Seed Entrepreneurs Association of Nepal (SEAN), Agro-vets, Seed Quality Control Center etc.

Key roles of supportive projects for dissemination and up scaling

• OFID-ICARDA Project "Enhancing Pulse production through utilization of rice-fallow with pulse as a second crop to improve food and nutritional security in Bangladesh and Nepal"

• Harvest Plus ICARDA Bio-fortification project" Development of lentil lines with high concentration of zinc and iron"

• IFAD-ICARDA Project" Enhancing food and Nutritional Security and Improved livelihoods through intensification of rice-fallow system with pulse crops in South Asia"

• IFAD-ICRISAT project Tag # 954" Harnessing The True Potential of Legumes; Economic and Knowledge Empowerment of Poor Rainfed Farmers in Asia"

• Agriculture and Food Security Project

• CIMMYT-Nepal Seed and Fertilizer Project, CSISA

• CLIMA Project, FORWARD, KISAN, Seed Companies,Agriculture Knowledge Centre (AKC), SMART Village, Seed Companies etc

Adoption trends of major grain legumes in Nepal

Adoption of lentil

Till date 14 lentil varieties have been released for general cultivation. Most demanded and adopted lentil varieties are Simal, Khajura-1, Khajura-2, Khajura-3, Khajura-4 and Shrada.Lentil is the wonderful, popular & most preferred food pulses of Nepalese people which shares about 64% in area and 67% in production out of total legumes [21]. Lentil was exported to aboard countries in worth was ~US$10 million in 2016.Lentil area has increased by 1.9 fold, production by 4.7 fold and productivity by 2.45 fold as compared with the year 1984/85. It is estimated that 58% adoption rate in lentil and an average yield increment of 300 kg/ha due to the improved varieties

Adoption of mungbean

Mungbean is popular in rice-wheat-mungbean in lowland irrigated areas of terai and inner terai and maize-mungbean-winter crops in upland cropping system. It was cultivated in 8266 ha area, 10468 mt production [22] and scarcely distributed legumes. More than 75% mungbean area are mainly concentrated in the eastern / central terai and remaining 25% area is in the western terai and foothills. Mungbean varieties viz. Pratikchya, Kalyan, Pratigya are highly demanded varieties across the country [23-28]. Besides pipeline varieties are Pant Mung-5, SML-668 and popular in mid and far western terai. It is estimated about 50% adoption rate of mungbean improved varieties in Nepal.

Adoption of *Phaseolus* bean (Rajma)

In Rajma crop single variety PB001 (PDR-14) has registered in Nepal. It is being grown as summer crop at high and mid hills, winter crop at terai. At Jumla, the adoption rate of Farmers preferred Phaseolus beans var. PB0001 was 60-75%. It has also been distributed to neighboring district of Humla, Dolpa, Mugu and Kalikot districts.Pipeline varieties of Rajma are Amber, Utkarsh, NL-1, Hetaude Rajma, KBL-3, KBL-2. Three pipeline varieties KBL-1, KBL-2 and KBL-3 are in the process of registration. In terai, about 40% adoption rate of PDR-14 is estimated [29-31].

Adoption of pigeonpea

Till date two pigeonpeavarieties Bageswori(LD) and Rampur Rahar-1(MD) were released for general cultivation. Now popular pigeonpeavarieties are ICP-7035, ICPL-86005, Dhanusha Local(LD), ICPL 88039 (SD). In pigeonpea; the adoption of rate Farmers Participatory Varietal Selection was Dhanusha local (60%), ICP7035 (20%), ICPL88039 (5%) in Dang. Over all about 15% adoption rate estimated of Rampur Rahar-1, Bageswori, ICP-7035, ICPL-86005, Dhanusha Local, ICPL88039 is estimated.

Adoption of Cowpea

Till date five cowpea varieties i.e. Aakash, Prakash, Surya, Malepatan-1 and Gajale Bodi has been released for general cultivation. However, popular varieties are Prakash, Surya, Gajale Bodi(Dual), Malepatan-1(Dual). In these days, there are highly demanded var. Gajale Bodi Lumbini and Karnali province. In cowpea about 45% adoption rate of Prakash, Surya both in terai and hills is estimated.

Impact from the supportive projects interventions

• Increase dietary intake of lentil and other pulses (45 g per person per annum)

• Average land holding of lentil farmer 0.142 ha, and with adoption of improved technology, approx., 918266 farm families getting benefitted for nutritional security.

• Increase involvement of Research& Development organizations in lentil scaling up (NTIS, PACT, RISM, KISAN, CYMMIT-NASF, AKC, NGOs etc.)

• Increase agro-processing units and exporters (VBSE)

• Increase seed business by 15 seed companies, 5 cooperatives and 4 farmers seed growers

• Being demands mini dal mill for value addition

• Creates job and start village level business for women by food products diversification of different legumes (Mungbean -Dalmoth, porridge, disserts, sweets, Pakaudaetc)

• Increase crop intensifications (Rice-winter crops-mungbean/cowpea/ blackgram)

• Increase collaborate works in Public Private Partnership (PPP) concept in infrastructural development (Go down, seed storage, Grader and cleaner, mill installments)

• Increase interest of local government in pulses such as lentil, mungbean, rajma, soybean, pigeonpeaetc

• Linking seed business with subsidiary business such as grain mills, credit facility, fertilizer cooperatives

Future strategies for increasing pulses productivity and production

Immediate/ short term strategy (5 years)

• Strengthen breeding program and varietal development through using local landraces and introduction of exotic materials (selection/Hybridization).
• Prioritize inclusion of local landraces in breeding program
• Collect local materials and obtain segregating materials from International Agricultural Research Centers (IARCs) for evaluation, selection and recommendation of varieties.
• Select the best adaptive lines through International Elite Nurseries (Segregating materials and stress tolerance accessions)
• Initiate breeding program on GL for stress tolerance (diseases, pests, drought and cold)
• Categorize breeding plan to develop short, medium, late maturity, drought, cold, biofortified grain legumes varieties which are better adapted to warmer, short season environments
• Develop bio-fortified legumes (Harvest Plus) and low-toxin grasspea for improved nutrition and health
• Focus quality breeding on exportable qualities like small seeded, red cotyledon and tasty lentil
• Revisit to fertilizers and seed rates needs to be recommend
• Optimize production package (variety, chemical fertilizers, seed treatment, rhizobium culture, pest management) and disseminate it as technology package for different crops.
• Plan for adequate quality source seed production within the NARC stations and through farm cooperatives/seed growers and supply source seed
• Strengthen seed delivery systems (availability of breeder seed, foundation seed, quality improved seed,
• Collaborate with other research station (DoAR, Surkhet) for blackgram and soybean seed production
• Strong international collaboration and linkages with IARS (ICRISAT/IITA/AVRDC/ICARDA)
• Popularization of short duration cowpea, blackgram and mungbean as catch crop in Rice- Wheat- Mungbean, Rice-Wheat-Blackgram, Rice-Lentil-Mungbean in terai/ inner terai and as relay crop in Rice-Maize/Cowpea/mungbean/blackgram in river basin/ foot hills.

• Identify sources of resistance for major disease and pests
• Develop integrated pest management (IPM) options for the management of diseases, insect pests and parasitic weeds.
• Research need for revision on macro and micro-nutrients (B, Mo, S, Zn) requirements
• Conduct experiments to standardize techniques of foliar spray of urea for balanced nutrition
• Identify the major problems of grain legumes in farmer's field with collaboration of Research station and KrishiGyanKendras (KGKs)
• Promote bed/ridge planting technique to enhance productivity and water use efficiency in pulses
• Work on socio-economic and policy issues for increasing pulses productivity and sustainability
• Promote mechanization (ZTD, bed planting) to minimize the cost of production
• Develop suitable agro-technology for stress environments i.e. Seed priming, pre-irrigation, ridge planting etc
• Develop efficient pulse based intercropping or mixed cropping system to ensure the food security and crop insurance
• Standardize agro-technology for early pigeonpea – wheat cropping system
• Identify short duration pulse crops in rice-wheat or maize based eco-system
• Develop integrated weed management technology for pulse based cropping system.
• Research on IPM and development of IPM package for important pest of legume crops (Cultural manipulation of the crop and its environment to encourage the activity of natural enemies, use of natural plant products and bio-pesticides alone or in combination with synthetic pesticides)
• Post emergence herbicide in particular for relay lentil/ conservation agriculture based farming
• Verify and validate on-station proven technologies in farmer's field of OR sites, KGKs and explore to integrate legumes in PMAMP (Zone and super zone program)
• Construct screen house for control environment research (hybridization, screening the germplasm and nucleus seed production etc)

Medium term strategy (5-10 Years)

• Improved methodologies and tools for genetic improvement (pre-breeding, advanced biometry, crop information system, etc.).

• Use of molecular tools to accesses variation for high yielding cultivar development

• Mutation & molecular breeding on soybean, blackgram and lentil

• Develop appropriate Resource conservation low cost technology and climate SMART production technology

• Crop simulation modeling on pulse crops to predict the crop productivity and sustainable use of water and other resources

• Research and promote better bet Agronomic Management to minimize Yield GAP between research station and at farm level

• Strengthen the technical capacity of seed companies, seed cooperatives and miller's staffs for effective seed and grain value chain extension services

• Capacity building in NARS programs

Long term strategy (> 10 years)

- Identify quantitative trait loci(QTL) in the context to climate change, drought, heat stress etc.
- In the process of Govt. restructuring slogans "Prosperous New Nepal, Happy Nepali" - Re-prioritize the legumes R4D based on the importance of legumes area and production scenario in province level
- Develop soybean varieties suitable for feed industries, seeking co-funding from feed industries
- Conduct research on integrated nutrient management through inclusion of legumes in the cropping pattern.
- Initiate physiological research
- Initiate research on underutilized or minor grain legumes such as ricebean, horsegram, fieldpea and fababean.
- Initiate research on postharvest management, value addition and utilization
- Breeding of inbred lines for variety development and breeding of new testers for hybrid program will go hand in hand.
- Selection of parents to develop breeding populations can be done together by considering their combining ability, genetic diversity, and market traits
- Exploitation of photo-thermo sensitivity in pigeonpea for hybrid breeding, diversification of hybrid parents, development of heterotic groups, refining seed technology and technology transfer to the farmers

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References

1. Graham PH, Vance CP (2003) Legumes: Importance and Constraints to Greater Use. Plant Physiol 131: 872-7.

2. FAOSTAT (2018) http://faostat.fao.org/site/339/default.aspx

3. MOAD (2019) Statistical information on Nepalese Agriculture. Government of Nepal, Ministry of Agricultural Development, Singhadarbar, Kathmandu, Nepal.

4. Mohanty S, Satyasai DK (2015) Feeling the Pulse Indian Pulses Sector. Mumbai: Department of Economic Analysis and Res (DEAR).

5. Cabrera C, Lloris F, Giménez R, Olalla M, López MC (2003) Mineral content in legumes and nuts: contribution to the Spanish dietary intake. The Science of the Total Environment 308: 1-14

6. Guillon F, Champ MM (2002) Carbohydrate fractions oflegumes: uses in human nutrition and potential for health. Br J Nutr 88: S293-306

7. Tosh SM, Yada S (2010) Dietary fibres in pulse seeds and fractions: Characterization, functional attributes, and applications. Food Res Internl 43: 450-60

8. Marlett JA, McBurney MI, SlavinJL (2002) Position of the American Dietetic Association: Health implications of dietary fiber. J Am Dietetic Assoc 102: 993-1000.

9. Champagne ET, Wood DF, Juliano BO, Bechtel DB (2004) Therice grain and its gross composition.In: ET Champagne(ed), Rice: Chemistry and Technology, 3rd (ed.). AACC, St.Paul, MN 77-107

10. Shewry PR (1993) Barley seed proteins. In: AW MacGregorand Bhatty RS(eds), Barley: Chemistry and Technology. AACC, St. Paul, MN 131-97.

11.Zuber MS, Darrah LL (1987) Breeding, genetics and seed corn production. In: SA Watson and Ramstad PE (eds), Corn: Chemistry and Technology. AACC, St. Paul, MN 31-51.

12. United States Department of Agriculture (2013) USDA National Nutrient Database for Standard Reference, Release25 (2009) http://www.ars.usda.gov/SP2UserFiles

13. Gowda CLL, Jukanti AK, Gaur PM (2014) Contribution of grain legumes in combating food and nutrition in-security in different regions of the world. In: The basics of human civilization - food, agriculture and humanity 2: 469-500

14. FAO (2002) Human vitamin and mineral requirement. Report of a joint FAO/WHO expert consultation, Bangkok, Thailand. http://www.fao.org/DOCREP/004/Y2809E/y2809e00.html

15.Chibbar RN, Baga M, Ganeshan S, Khandelwal RL (2004) Carbohydrate metabolism. In:C Wrigley, Corke H, WalkerCE(eds), Encyclopedia of grain science. Elsevier, London 168-79

16. Chibbar RN, Ambigaipalan P, Hoover R (2010) Molecular diversity in pulse seed starch and complex carbohydrates andits role in human nutrition and health. Cereal Chem 87: 342-52

17. Han IH, Baik BK (2006) Oligosaccharide content and composition of legumes and their reduction by soaking, cooking, ultrasound and high hydrostatic pressure. Cereal Chem 83: 428-33

18. Evans LT, Fischer RA (1999) Yield potential: its definition, measurement and significance. Crop. Sci. 39: 1544-51.

19. Dogra Atul (2014) Adoption and impact assessment of ICARDA funded projects implemented districts of Nepal

20. Magar DBT, Darai R, Gauchan D, A Sarker (2014) Varietal adoption and marketing of lentilin the mid and far western terairegion of Nepal. Adv Plants Agric Res 1: 164-70.

21. MOAD (2017) Statistical information on Nepalese Agriculture. Government of Nepal, Ministry of Agricultural Development, Singhadarbar, Kathmandu, Nepal.

22. MOAD (2016) Statistical information on Nepalese Agriculture. Government of Nepal, Ministry of Agricultural Development, Singhadarbar, Kathmandu, Nepal.

23. Agriculture Development Strategy (2015). http: //moad. gov.np/downloads.php?page =2 &id:O

24. Agriculture Development Policy (2016) http ://moad. gov.np/downloads.php?page --2&id:0

25. Climate Change policy http ://moste. gov.np/elibraryNational Adaptation Program of Action to Climate Change Final Report

26. National Seed Vision 2013-2025 http ://sqcc. gov.np/en/publications/

27. Food and Nutrition Security, Plan of Action (2015-2025)

28. Evans LT (1993) Crop evaluation, adaptation and yield (Cambridge University Press)

29. Egli DB (2008) Soybean yield trends from 1972 to 2003 in mid-western USA. Field Crops Res. 106: 53-9

30. Cassman KG,Pingali PL (1995) Intensification of irrigated rice systems: learning from the past to meet future challenges. GeoJournal 35: 299-305, doi:10.2307/41146410.

31. Darai R, Sarker A Sah RP, Pokhrel K, Chaudhary R (2017) AMMI biplot analysis for genotype X environment interaction on yield trait of high Fe content lentil genotypes in terai and mid-hill environment of Nepal. Ann. Agric. Crop Sci. 2: 1026-30.