REVIEW ARTICLE Agricultural Reviews, Volume 47 Issue 1: 93-99 (February 2026)

Importance of Integrated Nutrient Management for Pulse Crops Amidst Climate Change in India: A Review

V.K. Patel[1], S.V. Singh[1], C. Patel[2], S.N. Ingle[2], S.P. Das[2], A.K. Singh[3], V. Kumar[2]

10.18805/ag.R-2747

ABSTRACT

The challenge of increasing food production to meet the needs of current and future human populations, while adopting environmentally friendly strategies for sustainable agricultural development, demands significant attention. In this context, we explore the critical role, potential and climate challenges of integrated nutrient management (INM) in pulse crops in India. INM has been proposed as a promising strategy to address these issues by improving crop productivity, enhancing plant performance and increasing resource efficiency, all while protecting the environment and maintaining resource quality. This review investigates the importance, potential and climate-related challenges faced by pulse crops. A comprehensive analysis of the literature indicates that INM can boost crop yields by 8-150% compared to conventional practices, improve water-use efficiency and increase economic returns for farmers. Additionally, INM enhances grain quality, soil health and overall sustainability. Crop simulation models reveal that climate change, characterized by rising temperatures and increased greenhouse gas (GHG) emissions, significantly reduces productivity. Various approaches and perspectives for advancing INM shortly are also discussed. Strong evidence supports the notion that INM could serve as an innovative and eco-friendly strategy for achieving sustainable productivity in the face of climate change.

Key words: Climate change, Integrated nutrient management, Productivity, Pulse.

India, the seventh-largest country by area and the most populous in the world (UNDESA, 2022), accounts for nearly 18% of the global population while covering approximately 2.4% of the world's surface. The country's horticulture sector has proven to be more profitable and productive than its traditional agricultural sector, contributing about 33% to the agriculture Gross Value Added (GVA), thus playing a significant role in the Indian economy. Currently, India produces approximately 320.48 million tons of horticultural produce, surpassing food grain production and does so on a much smaller area (25.66 million hectares for horticulture versus 127.6 million hectares for food grains). The productivity of horticultural crops is notably higher (12.49 tons per hectare) compared to that of food grains (2.23 tons per hectare) (Anonymous, 2020).

India's large population, primarily vegetarian, relies heavily on plant-based sources for its daily protein requirements. Pulses are a crucial source of proteins, vitamins and minerals, often called "poor man's meat" and "rich man's vegetable," contributing significantly to the nation's nutritional security. Currently, India is both the largest producer and consumer of pulses globally and also a significant importer. Between 2022-23, India imported 2.77 million tons of pulses annually (DGCIS, 2022-23). By 2050, India is projected to transition from being a net importer to a net exporter of pulses if current trends continue (Singh *et al.,* 2013).

Component of integrated nutrient management

Integrated Nutrient Management (INM) involves a synergistic approach to maintaining soil fertility and plant health by combining organic and inorganic nutrient sources. Key components of INM include the use of organic manures such as farmyard manure, green manure and vermicompost (Meena *et al.,* 2007) to enhance soil organic matter and microbial activity. Applied biofertilizers, including Rhizobium, Azospirillum and phosphate-solubilizing bacteria (Singh *et al.,* 2016), play a crucial role in fixing atmospheric nitrogen and making phosphorus available to plants (Fig 1). Chemical fertilizers supply essential macro and micronutrients, ensuring balanced nutrient availability. Soil amendments like lime and gypsum are used to correct pH and improve soil structure, while crop rotation and diversification, particularly with legumes, help sustain soil nitrogen levels and break pest and disease cycles. Precision farming techniques, such as soil testing and site-specific nutrient management, optimize fertilizer

[1]Department of Horticulture, Shri Durga Ji Post Graduate College, Chandeshwar, Azamgarh-276 128, Uttar Pradesh, India.
[2]Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Bhagalpur-813 210, Bihar, India.
[3]Department of Agricuitural Chemistry and Soil Science, Udai Pratap College, Varanasi-221 002, Uttar Pradesh, India.

Corresponding Author: C. Patel, Department of Soil Science and Agricultural Chemistry, Bihar Agricultural University, Bhagalpur-813 210, Bihar, India. Email: chandrabhanpatel@bausabour.ac.in

How to cite this article: Patel, V.K., Singh, S.V., Patel, C., Ingle, S.N., Das, S.P., Singh, A.K. and Kumar, V. (2026). Importance of Integrated Nutrient Management For Pulse Crops Amidst Climate Change In India: A Review. *Agricultural Reviews.* **47(1):** 93-99. doi: 10.18805/ag.R-2747.

Submitted: 15-07-2024 **Accepted:** 25-01-2025 **Online:** 26-04-2025

application. This comprehensive approach ensures enhanced crop yields, improved soil fertility and reduced environmental impact.

Nutritional value of different pulses

Common pulses in India include green gram, red gram, bengal gram, horse gram, cluster bean, field bean and cowpea. These pulses typically have high protein content, often more than twice that of cereal grains, constituting about 20% of the dry weight of seeds (Table 1). Some legumes, such as soybeans, have protein content as high as 40% (Pedrosa *et al.,* 2021). Pulses also contain about 55-60% of total carbohydrates, including starch, soluble sugars, fiber and unavailable carbohydrates and are

Table 1: Nutritive value in different pulse grains in 100 grams.

Pulse name	Energy kcals	Moisture (g)	Protein (g)	Fat (g)	Carb (g)	Fibre (g)	Mineral (g)	Calcium (mg)	Phosphorus (mg)	Iron (mg)
Bengal gram, whole	360	10	17	5	4	4	3	202	312	5
Bengal gram, dhal	372	10	21	6	1	1	3	56	331	5
Bengal gram, roasted	369	11	22	5	1	1	2	58	340	9
Black gram, dhal	347	11	24	1	1	1	3	154	385	4
Cowpea	323	13	24	1	3	4	3	77	414	9
Field bean, dry	347	10	25	1	1	1	3	60	433	3
Green gram, whole	334	10	24	1	4	4	3	124	326	4
Green gram dhal	348	10	24	1	1	1	3	75	405	4
Horse gram, whole	321	12	22	0	5	5	3	287	311	7
Kherasi dhal	345	10	28	1	57	2	2	90	317	6
Lentil	343	12	25	1	59	1	2	69	293	7
Moth beans	330	11	24	1	56	4	3	202	230	9
Peas green	93	73	7	0	16	4	1	20	139	1
Peas dry	315	16	20	1	56	4	2	75	298	7
Peas roasted	340	10	23	1	59	4	2	81	345	6
Rajmah	346	12	23	1	61	5	3	260	410	5
Redgram, dhal	335	13	22	2	58	1	3	73	304	3
Redgram tender	116	65	10	1	17	6	1	57	164	1
Soyabean	432	8	43	19	21	4	4	240	690	1

Source: (Gopalan *et al.,* 2014).

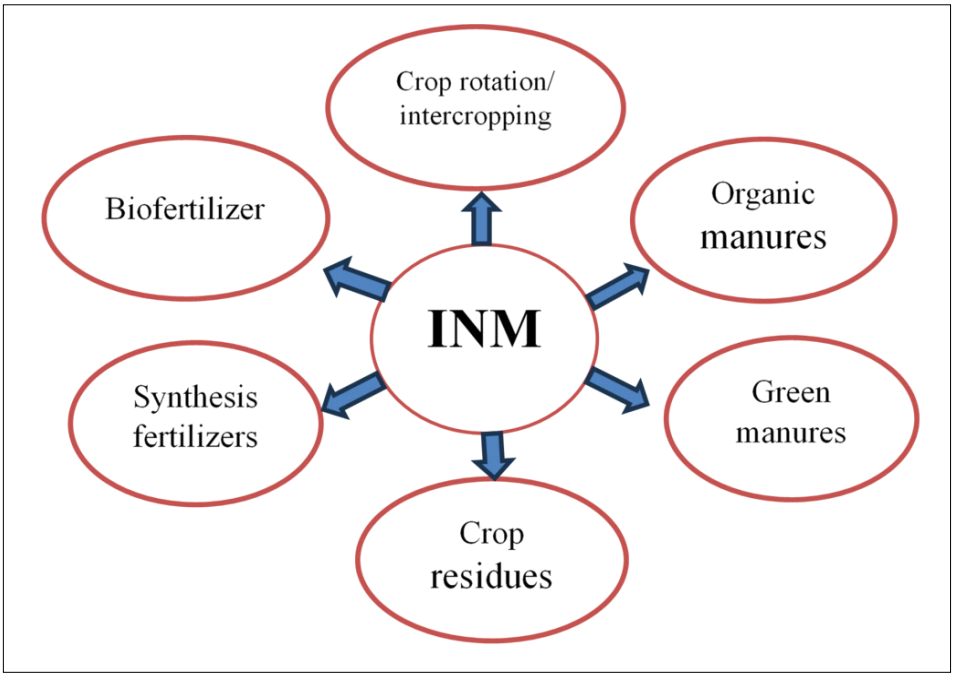


Fig 1: Components of integrated nutrient management (INM).

important sources of calcium, magnesium, zinc, iron, potassium and phosphorus. They also contain small amounts of carotene, a provitamin (Gopalan *et al.,* 2014; Fakeerappa and Amit, 2015).

Toxic constituents and their elimination in pulses

Pulses contain both edible and inedible types, with some edible legumes harboring toxic principles. Eliminating these toxins is crucial for their safe consumption. Thermolabile factors, such as inhibitors of trypsin, chymotrypsin and amylase haemagglutinins, impede digestion. Additionally, legumes contain goitrogens, toxic saponins, cyanogenic glycosides and alkaloids (Enneking and Wink, 2000). Tannins and phenolic compounds are mainly found in the seed coat (Dueñas *et al.,* 2002; Reddy *et al.,* 1985). Soaking, heating and fermentation can reduce or eliminate most of these toxic factors (Yasmin *et al.,* 2008; El-Adawy, 2002; Kumar *et al.,* 2022).

Area, production, productivity and import of pulses in India

India cultivates pulses on more than 28 million hectares, producing 25.46 million tons in 2020-21, making it the largest pulse-producing country globally, with a productivity of 885 kg/ha, a significant increase over the past five years (Table 2). Major pulses grown in India include chickpeas, pigeon peas, mung beans, black gram, lentils, peas and various beans, primarily in regions like Madhya Pradesh, Rajasthan, Maharashtra, Karnataka, Uttar Pradesh, Coastal Andhra Pradesh, Gujarat, Tamil Nadu, Jharkhand, Odisha, Chhattisgarh, Telangana, Bihar and the West Bengal delta. Food grains occupy 65% of India's total gross cropped area, with cereals at 50% and pulses at about 14% (MoAFW, Govt. of India 2021).

Despite this, domestic production does not meet internal demand, necessitating imports of about 3.5 million tons of pulses annually. In 2015-16, pulse imports exceeded 5.2 million tons, costing around ₹ 26,000 crore (US $3.95 billion). Pulse imports had a mixed trend from 2017-18 to 2021-22. During the previous five years, pulse imports ranged from 23.16 to 56.08 lakh tons, with the largest amount reported in 2017-18. Overall, there has been a declining scenario/trend in pulses importing and saving foreign cash (Anonymous, 2023). The area under pulses increased from 24.91 million hectares in 2015-16 to 30.37 million hectares in 2021-22, with yield rising from 656 kg/ha to 888 kg/ha. Projections indicate that the current import dependency of around 9% (2020-21) will decline to 3.6% by 2030-31 (Table 3). This reduction in dependency can be achieved with an additional production of 1.5-2 million tons beyond the current targets.

Impact of climate change on pulse crops

Over the past three decades, global awareness of climate change has grown significantly, raising widespread concern among scientists and governments about its implications (Cooper *et al.,* 2009; Jesh *et al.,* 2010). According to the Intergovernmental Panel on Climate Change (IPCC, 2007), CO_2 levels are projected to rise to 605-755 ppm by 2070, with global temperatures increasing by 1.5°C between 2015-2050 and by 3.0°C between 2050-2100.

Yadav *et al.* (2016) simulated the impact of climate change on pigeon pea productivity in Varanasi using the Decision Support System for Agrotechnology Transfer (DSSAT v4.6.1). Their study showed a dramatic 96% decrease in pigeon pea productivity with a 3.0°C temperature increase above normal Conversely, pulse crop productivity increased under elevated CO_2 concentrations (Table 4). Rao *et al.* (2013) reported that high temperatures during the reproductive stage adversely affect the development of reproductive tissues, growth regulators, photosynthate supply, pollen production, viability, fertilization and seed set, leading to reduced productivity in pigeon pea.

In green gram, temperatures above 42°C during summer cause seed hardening due to incomplete sink development. Field peas, more adapted to low

Table 2: Area, production, productivity and import of pulse in India.

Year	Area (mha)	Production (mt)	Productivity (kg ha^{-1})	Import (mt)
2013-14	25.22	19.26	764	3.64
2014-15	23.55	17.15	728	4.58
2015-16	24.91	16.32	655	5.50
2016-17	29.45	23.13	786	6.66
2017-18	29.81	25.42	853	5.61
2018-19	29.16	22.08	757	2.52
2019-20	27.99	23.03	823	2.14
2020-21	28.78	25.46	885	2.46
2021-22	31.00	26.96	869	2.69

Note: mha= Million hectare and mt= Million tonnes (Singh *et al.,* 2022).

Table 3: Present status, target and projections of production, demand and requirement of import of pulse.

Pulse	Present status	Target		Projections	
	2020-21	2021-22	2028-29	2029-30	2030-31
Production	25.72	26.96	29.79	30.75	33.95
Demand	28.18	29.26	31.83	32.64	35.23
Import requirement	2.46	2.3	2.04	1.89	1.28
Dependency on import	9%	8%	6%	5.70%	3.60%

Source: Press information bureau, Ministry of land B, Govt. of India.

temperatures, shows retarded growth below 7°C. High daytime temperatures beyond 40°C during the reproductive phase of winter pulses result in failed anthesis and pod setting, inducing seed hardening. The failure of anthesis at high temperatures is primarily due to poor pollen germination, stigma receptivity and ovule viability above 35°C (Basu *et al.,* 2009). Field peas are more sensitive to high temperatures than chickpeas and lentils, with significant impacts during critical growth periods (McDonald and Paulsen, 1997). Lentils, particularly sensitive to temperatures above 30°C during the reproductive phase, experience pod and flower abortion, significantly reducing grain yield and quality (Erskine *et al.,* 1994; Sehgal *et al.,* 2017; Sita *et al.,* 2017). Increasing post-monsoon rainfall in January and February detrimentally affects *rabi* pulses during their reproductive period (Bera, 2021).

Introducing pulses for climate resilience

Incorporating pulses into farming systems can enhance resilience to climate change. Agroforestry systems, including pulses like pigeon peas, support adaptation through income diversification, increased resilience to climate extremes and improved productivity. Furthermore, trees in agroforestry systems sequester more carbon than field crops alone, aiding both adaptation and mitigation.

Integrated nutrient management (INM) and pulse crops

Integrated nutrient management (INM) combines natural (such as pulses, oilseeds and bio-fertilizers) and *man-made soil nutrients* to maintain soil fertility and optimize plant nutrient supply, enhancing crop productivity while preserving soil health for future generations. INM encourages long-term planning and environmental consideration among farmers.

Effect of INM on pulse crops

Kumar *et al.* (2021) study conducted during 2017-18 and 2018-19 on French bean (var. Arka Suvidha) with eight treatments *viz* T_1 (100% NPK through inorganic source), T_2 (75% NPK through inorganic + 25% N through FYM), T_3 (75% NPK through inorganic + 25% N through Vermicompost), T_4 (50% NPK through inorganic + 50% N through FYM), T_5 (50% NPK through inorganic + 50% N through Vermicompost), T_6 (25% NPK through inorganic + 75% N through FYM), T_7 (25% NPK through inorganic + 5% N through Vermicompost), besides an absolute control *i.e.,* T_8 (no organic, inorganic applied). The benefit-cost ratio is also calculated to compare the practical feasibility of various treatment levels. The experiment was laid out in a randomized block design with three replications. The variance analysis technique analyzed the experimental data on growth and yield attributes. The treatment level III *i.e.* 75% NPK through inorganic + 25% N through Vermicompost) exhibited the highest yield (95.61 q /ha.) and benefit-cost ratio (2.16).

Dhakal *et al.* (2016) conducted a field experiment at Varanasi (Uttar Pradesh) during the *kharif* season of 2013 to study the influence of integrated nutrient management on green gram. They applied three sources of nutrients *viz*. inorganic, organic and bio-fertilizers were used in twelve combinations with randomized block design. Among different combinations, significant improvement in number of nodules/plant (80.97), dry weight of nodules (32.89 mg/ plant), yield attributes, seed yield (12.34 q t/ha), harvest index (28.32%), nutrient content, available NPK and organic carbon after harvest in soil recorded with application of nutrients through 75% RDF + 2.5 t/ha vermicompost + Rhizobium + Phosphate solubilizing bacteria (PSB) as compared to other combinations. Vermicompost positively impacts soil properties and enhances the mineralization of nitrogen, phosphorus and potassium, driven by the release of organic acids. In legume crops, substantial organic residue from leaf fall and rhizodeposition further aids soil fertility.

Growth and yield parameters of pigeon pea under INM practices

Research has demonstrated that Integrated Nutrient Management (INM) practices can significantly enhance the growth and yield of pigeon pea. Notable studies include:

In a pigeon pea and pearl millet intercropping system, the application of 50% RDF, 5 t/ha vermicompost and biofertilizers yielded significantly higher grain outputs for

Table 4: Pulse crop and climate change impact on crop phenology and productivity.

Crop name	Climate change	Impact on crop	References
Pigeon pea	3.0°C > normal	Yield decreased up to 96.0%	Yadav *et al.* (2016)
Green gram	> 42°C	Failure of anthesis, pod setting and induces hardening of seeds	-
Field pea	> 40°C	Failure of anthesis, pod setting and induces hardening of seeds	-
Lentil	> 30°C	Pod and flower abortion	Erskine *et al.,* 1994; Sehgal *et al.,* 2017; Sita *et al.,* 2017
Rabi pulses	Rainfall in January and February	Detrimental factor for *Rabi* pulses particularly, during its reproductive period	Bera, 2021

both crops (19.16 q/ha for pigeon pea and 16.61 q/ha for pearl millet) compared to the use of 50% RDF and biofertilizers alone (15.89 q/ha and 13.33 q/ha respectively) (Gholve *et al.,* 2005).

Patil and Shete (2008) reported that the application of 50% RDF, 5 t/ha FYM and biofertilizers in a pigeon pea and pearl millet intercropping system proved to be a suitable practice for economizing inorganic fertilizer use while sustaining soil health and productivity.

Nutrient content, uptake and soil status

Various studies have highlighted the benefits of INM on nutrient content and soil health:

In a study on *rabi* maize, applying 120 kg N/ha plus 1.5 t/ha vermicompost resulted in significantly higher nutrient content and uptake than 80 kg N/ha plus 1.5 t/ha vermicompost and control.

Tripathi *et al.* (2007) reported that applying bio-compost at a rate of 5 t/ha, combined with 75% of the recommended dose of nitrogen and phosphorus through fertilizers (with a full recommended dose of 120-60-60 kg N-P-K/ha), resulted in increased organic carbon and nitrogen availability in the soil after harvesting the maize crop.

Singh and Nepalia, (2009) evaluated and developed an integrated nutrient management package for quality protein maize in southern Rajasthan during the rainy seasons of 2003 and 2004. Three fertilizer levels (75% RDF, 100% RDF, *viz* 90 kg N + 40 kg P 20 5/ha and 125% RDF) and their three sources of organic manure (control, farmyard manure and vermicompost) and two phosphorus sources (die-ammonium phosphate and single super phosphate). The FYM and vermicompost used as additional doses over and above the treatments of fertilizer levels. Application of 125% RDF significantly enhanced growth and grain yield and proved profitable compared to 100% and 75% RDF. It is concluded that the application of 125% RDF through urea, single super phosphate, or die-ammonium phosphate along with 10 tons of FYM or 5 tons of vermicompost/ha forms an ideal module of INM for higher productivity of quality protein maize.

Quality and soil fertility

Studies have shown that INM improves both crop quality and soil fertility:

Yadav *et al.* (2019) reported 16 combinations that comprised four levels of nitrogen (N), *i.e.* 0, 100, 125 and 150 kg/ha and four doses of poultry manure (PM), *i.e.* 0, 10, 20 and 30 t/ha. The highest grain yield (g/plant) recorded in treatment 125 kg/ha N + 10 t/ha PM. The lower bulk density value of 1.12 g/cm^3 was noticed in treatment 0 kg/ha N + 10 t/ha PM and the maximum was observed in treatment 150 kg/ha N + 30 t/ha PM which was 1.29 g/cm^3. So, the treatment combinations (T_{10}) of 125 kg/ ha Nitrogen through inorganics plus 10 t/ha poultry manure through organics had significant differences as compared to all others. This might be due to the ready supply of nutrients through inorganic in the initial stages of crop growth slow release of nitrogen and a steady supply of other nutrients over an extended period of crop growth by organics.

Tetarwal *et al.* (2011) Application of 100% RDF (40-15-00 kg N-P-K/ha) plus 10 t/ha FYM resulted in maximum NPK uptake by maize and improved soil N and P status. Kalhapure *et al.* (2013) reported significantly higher organic carbon, available N, P_2O_5 and K_2O in soil with 25% RDF (30-15-15 kg N-P-K/ha) plus biofertilizers and green manuring with sunn hemp plus compost.

Effect of INM on soil fertility

Several studies underscore the positive impact of INM on soil fertility. The application of FYM alone or in combination with chemical fertilizers significantly increased the residual status of available nitrogen and phosphorus in soil (Dudhat *et al.,* 1997). Integrated application of recommended fertilizers with FYM significantly enhanced available soil nitrogen and improved soil fertility status Babalad (2000). Dubey and Vyas (2010) reported that 50% RDF plus 5 t/ha FYM and biofertilizers improved soil health by enhancing organic carbon and available nutrient status while reducing soil bulk density. Singh and Singh (2012) reported that soil-test-based NPK and FYM integration improved pigeon pea and wheat grain yield and soil health. Meena *et al.* (2012) application of 75 kg P_2O_5/ha resulted in higher total nitrogen, phosphorus, potassium and sulfur uptake compared to 25 kg P_2O_5/ha and control Pandey *et al.* (2013) found that pigeon pea and black gram intercropping with FYM or vermicompost and RDF improved soil bulk density, organic carbon and available N, P and K content

INM in french beans

Jayashri and Kushwah, (2017) conducted a field experiment at the vegetable research field RVSKVV, Gwalior during the rabi season 2013-14 to studied to evaluate the influence of integrated nutrient management on root growth, flowering and quality of seed in French beans. They applied of six nutrient levels *viz.,* N1: Vermicompost (10 t/ha) + PSB (15 g/kg seed) + P_2O_5 (80 kg/ha) + K_2O (80 kg/ha), N_2: Vermicompost (10 t/ha) + Rhizobium (15 g/kg seed) + PSB (15 g/kg seed) + P_2O_5 (80 kg/ha) + K_2O (80 kg/ha), N_3: Vermicompost (10 t/ha) + N (25 kg/ha) + Rhizobium (15 g/kg seed) + PSB (15 g/kg seed) + P_2O_5 (80 kg/ha) + K_2O (80 kg/ha), N_4: Vermicompost (10 t/ha) + N (50 kg/ha) + Rhizobium (15 g/kg seed) + PSB (15 g/kg) + P_2O_5 (80 kg/ha) +K_2O (80 kg/ha), N_5: Vermicompost (10 t/ha) + N (75 kg/ha) + Rhizobium (15 g/kg seed) + PSB (15 g/kg) + P_2O_5 (80 kg/ha) + K_2O (80 kg/ha), N_6: Vermicompost (10 t/ha) + N (100 kg/ha) + Rhizobium (15 g/kg seed) + PSB (15 g/kg) + P_2O_5 (80 kg/ha) + K_2O (80 kg/ha). Specifically, the treatment N_4 nitrogen combined with Rhizobium and PSB produced superior results, suggesting that higher nutrient availability supports enhanced root development, more robust flowering and better-quality seeds.

CONCLUSION

Integrated Nutrient Management (INM) is pivotal in enhancing agricultural yield while promoting biological, water and soil restoration. Research has demonstrated that INM practices significantly improve soil fertility and crop productivity. The integration of organic and inorganic fertilizers is widely recognized for its ability to increase synchrony, enhance fertilizer efficiency and mitigate environmental issues. To effectively promote INM in India, extension organizations must educate farmers about the critical issues of declining soil health, unsustainable agricultural practices, environmental pollution and climate change. Despite being the leading producer of pulses, India is also the largest consumer and importer of these crops' output. The decreasing per capita availability and escalating prices highlight the urgent need for a pulse revolution in the country. Achieving self-sufficiency in pulse production requires a comprehensive approach that involves the judicious use of resources, the utilization of genetic resources and the adoption of advanced technologies. By doing so, India can ensure sustainable production of pulse and secure its food supply for future generations amidst climate change.

Conflict of interest

All authors declare that there is no conflict of interest.

REFERENCES

Anonymous. (2020). 2nd Advance Estimates of 2019-20 of Horticulture Crops. Press Information Bureau, Government of India, Ministry of Agriculture and Farmers Welfare.

Anonymous. (2023). Annual report (DPD/Pub./TR/46/2022-23). Directorate of Pulses Development, Vindhyachal Bhavan, Bhopal, Madhya Pradesh. Retrieved from https://dpd.gov.in/AbtRep.html.

Anonymous. (2023). Pulses production and import trends in India: An overview. Ministry of Agriculture and Farmers Welfare, Government of India.

Babalad, H.B. (2000). Integrated nutrient management for sustainable production in soybean cropping system (Doctoral dissertation).

Basu, P.S., Ali, M. and Chaturvedi, S.K. (2009). Terminal heat stress adversely affects chickpea productivity in Northern India: Strategies to improve thermotolerance in the crop under climate change. In: W3 Workshop Proceedings: Impact of Climate Change on Agriculture New Delhi: International Society of Photogrammetry and Remote Sensing. **23:** 189-193.

Bera, A. (2021). Impact of changing rainfall patterns on pulse production in the *Rabi* season. *J. Soil Water Conserv*. **20(4):** 384-391.

Byjesh, K., Kumar, S.N. and Aggarwal, P.K. (2010). Simulating impacts, potential adaptation and vulnerability of maize to climate change in India. *Mitig. Adapt. Strateg. Glob. Change.* **15(5):** 413-431.

Cooper, P., Rao, K.P.C., Singh, P., Dimes, J., Traore, P.S., Rao, K., Dixit, P. and Twomlow, S.J. (2009). Farming with current and future climate risk: Advancing a hypothesis of hope for rainfed agriculture in the semi-arid tropics. *J. Semi-Arid Trop. Agric. Res.* **7:** 1-19.

Dhakal, Y., Meena, R.S. and Kumar, S. (2016). Effect of integrated nutrient management on nodulation, yield, quality and available nutrient status in soil after harvest of greengram. *Legume Research.* **39(4):** 590-594. doi: 10.18805/LR-4635.

Directorate General of Commercial Intelligence and Statistics. (2023). Foreign trade statistics of India 2022-23. Ministry of Commerce and Industry, Government of India.

Dubey, S. and Vyas, M.D. (2010). Integrated nutrient management in pigeonpea + soybean intercropping system under rainfed conditions. *Mysore J. Agric. Sci.* **44(4):** 781-785.

Dudhat, R.S., Bhan, V.M. and Bansal, R.K. (1997). Effect of organic and inorganic fertilizers on soil fertility and crop productivity in a wheat-pulses cropping system. *Indian J. Agron.* **42(2):** 266-269.

Dueñas, M., Hernandez, T. and Estrella, I. (2002). Phenolic composition of the cotyledon and the seed coat of lentils (*Lens culinaris* L.). *Eur. Food Res. Technol.* **215:** 478-483.

El-Adawy, T.A. (2002). Nutritional composition and antinutritional factors of chickpeas (*Cicer arietinum* L.) undergoing different cooking methods and germination. *Plant Foods Hum. Nutr.* **57(1):** 83-97.

Enneking, D. and Wink, M. (2000). Towards the Elimination of Anti-Nutritional Factors in Grain Legumes. In: Linking Research and Marketing Opportunities for Pulses in the 21st Century, [Knight, R. (Ed.).]. (pp. 671-683).

Erskine, W., Muehlbauer, F.J. and Smithson, J.B. (1994). Genotypic variation for seed yield and its components in lentil. *Euphytica.* **75(2):** 145-149.

Fakeerappa, P. and Amit, S. (2015). Nutritional and health benefits of pulses. *J. Nutr. Food Sci.* **5(3):** 375-381.

Gholve, S.H., Shinde, C.B. and Gaikwad, S.H. (2005). Efficacy of integrated nutrient management for pigeon pea-pearl millet intercropping system under dryland conditions. *J. Maharashtra Agric. Univ*. **30(1):** 41.

Gopalan, C., Rama ,S.B.V. and Balasubramanian, S.C. (2014). Nutritive value of Indian foods. National Institute of Nutrition. ICMR, Hyderabad. p. 161.

Intergovernmental Panel on Climate Change (IPCC). (2007). Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Cambridge University Press.

Jayashri, G. and Kushwah, S.S. (2017). Field experiment on vegetable crop response to nutrient management practices at RVSKVV, Gwalior during the *rabi* season 2013-14. *J. Agric. Res.* **9(1):** 45-52.

Kalhapure, R.S., Zode, B.R. and Kharche, V.S. (2013). Impact of integrated nutrient management on soil nutrient status and yield of maize in Konkan region of Maharashtra. *J. Soil Water Conserv.* **12(4):** 294-300.

Kumar, U., Prasad, K., Prasad, S.S. and Sinha, B.M. (2021). Integrated nutrient management studies for higher productivity of French bean (*Phaseolus vulgaris* L.) in calcareous soil of Bihar, India. *Legume Research - An International Journal.* doi:10.18805/LR-4399.

Kumar, Y., Basu, S., Goswami, D., Devi, M., Shivhare, U.S. and Vishwakarma, R.K. (2022). Anti-nutritional compounds in pulses: Implications and alleviation methods. *Legume Sci.* **42:** e111.

McDonald, G.K. and Paulsen, G.M. (1997). High-temperature effects on photosynthesis and water relations of grain legumes. *Plant Soil.* **196:** 47-58.

Meena, R., Kumar, S. and Sharma, D.K. (2019). Effect of nitrogen and poultry manure on yield and nutrient uptake by maize (*Zea mays*). *Indian J. Agric. Sci.* **89(11):** 1979-1981.

Ministry of Agriculture and Farmers Welfare (MoAFW), Government of India. (2021). Annual Report 2020-21. Retrieved from https://www.agricoop.nic.in/.

Pandey, A., Singh, B., Sharma, R. and Gupta, M. (2013). Effect of pigeon pea and black gram intercropping with FYM, vermicompost and recommended dose of fertilizers on soil bulk density, organic carbon and available N, P and K. *Indian J. Soil Sci.* **47(3):** 211-218.

Patil, R.S. and Shete, A.M. (2008). Effect of integrated nutrient management on growth, yield and economics of pigeon pea and pearl millet intercropping system. *Agric. Sci. Dig.* **28(1):** 42-44.

Pedrosa, M.M., Guillamón, E. and Arribas, C. (2021). Autoclaved and extruded legumes as a source of bioactive phytochemicals: A review. *Foods.* **10(2):** 1-34. https://doi.org/10.3390/foods 10020379.

Rao, C.A.R., Raju, B.M.K., Rao, A.V.M.S., Rao, K.V., Rao, V.U.M., Ramachandran, K., Venkateswarlu, B. and Sikka A.K. (2013). Atlas on vulnerability of Indian agriculture to climate change. Hyderabad: Central Research Institute for Dryland Agriculture.

Reddy, N.R., Pierson, M.D., Sathe, S K. and Salunkhe, D.K. (1985). Dry bean tannins: A review of nutritional implications. *J. Am. Oil Chem. Soc.* **62(3):** 541-549.

Sehgal, A., Sita, K., Kumar, J., Kumar, S., Singh, S., Siddique, K.H. and Nayyar, H. (2017). Effects of drought, heat and their interaction on the growth, yield and photosynthetic function of lentil (*Lens culinaris* Medikus) genotypes varying in heat and drought sensitivity. *Front. Plant Sci.* **8:** 1776.

Singh, A.K., Bharati, R.C., Manibhushan, N.C. and Pedpati, A. (2013). An assessment of faba bean (*Vicia faba* L.) current status and future prospect. *African Journal of Agricultural Research.* **8(50):** 6634-6641.

Singh, A.K., Bhatt, B.P., Sundaram, P.K., Kumar, S., Bahrati, R.C., Chandra, N. and Rai, M. (2012). Study of site-specific nutrients management of cowpea seed production and their effect on soil nutrient status. *J. Agric. Sci.* **4(10):** 191-198.

Singh, D. and Nepalia, V. (2009). Influence of integrated nutrient management on quality protein maize (*Zea mays*) productivity and soils of southern Rajasthan. *Indian J. Agric. Sci.* **79(12):** 1020-1022.

Singh, D., Singh, C.K., Tomar, R.S.S., Chaturvedi, A.K., Shah, D., Kumar, A. and Pal, M. (2016). Exploring genetic diversity for heat tolerance among lentil (*Lens culinaris* Medik.) genotypes of variant habitats by simple sequence repeat markers. *Plant Breed.* **135:** 1-10.

Singh, J.M., Kaur, A., Chopra, S., Kumar, R., Sidhu, M.S. and Kataria, P. (2022). Dynamics of production profile of pulses in India. *Legume Research*. **45(5):** 565-572. doi: 10.18805/LR-4274.

Sita, K., Mishra, A. and Kumar, A. (2017). Effect of terminal heat stress on reproductive stages of lentil. *Int. J. Agric. Environ. Biotechnol.* **10(2):** 179-183.

Tetarwal, S.P., Kumar, M. and Gupta, A. (2011). Effect of integrated nutrient management on nutrient uptake by maize and soil fertility status. *Indian J. Agric. Sci.* **81(7):** 671-674.

Tripathi, A.K., Singh, S.K. and Sharma, K. (2007). Effect of integrated nutrient management on soil nutrient status and yield of maize. *Indian J. Agron.* **52(1):** 37-40.

United Nations Department of Economic and Social Affairs, Population Division. (2022). World population prospects 2022: Summary of results. UN DESA/POP/2022/TR/NO. 3.

Yadav, M.K., Singh, R.S., Singh, K.K., Mall, R.K., Patel, C., Yadav, S.K. and Singh, M.K. (2016). Assessment of climate change impact on pulse, oilseed and vegetable crops at Varanasi, India. *J. Agrometeorol.* **18(1):** 13-21.

Yasmin, A., Zeb, A., Khalil, A.W., Paracha, G.M. and Khattak, A.B. (2008). Effect of processing on anti-nutritional factors of red kidney bean (*Phaseolus vulgaris*) grains. *Food Bioprocess Technol.* **1(4):** 415-419.