**Present Status and Future Research Strategies of Winter Legume Crops in Nepal**

**ABSTRACT**

Grain legume cultivation is the fundamental part of the Nepalese agriculture production systems, as these crops can be grown in a wide range of land from fertile to degraded or marginal soils, and also because of the *Dal-Bhat-Tarkari* eating habits of its populace. These crops occupied about 11% of the country’s total cultivated land, and fourth in the area and production after rice, maize, and wheat. Grain legume crops are also called ‘poor man’s meat’, and these crops have a significant role in increasing cropping intensity and crop diversification. Among the grain legume crops, lentil (*Lens culinaris* Medikus), chickpea (*Cicer arietinum* L.; *Cicer kabulium.*), kidney bean (*Phaseolus vulgaris* L.), grasspea (*Lathyrus sativus* L*.*), fababean (*Vicia faba* L.), and field pea (*Pisum sativum* L.) are the main legume crops for the winter season. The Grain Legume Research Program (GLRP), Khajura has released and registered fourteen varieties of lentil, seven varieties of chickpea, and one variety of kidney bean for different agro-ecological domains with their improved cultivation practices, *i.e.*, agronomic and disease and pest management, but this program has not been able to release any variety of grasspea, fababean, and field pea.

**Key words:** Nepal; grain legumes; varieties; technology

**1. Introduction**

Grain legumes are the fundamental part of the Nepalese agriculture production systems, as the source of protein, income and soil fertility improvement. These crops can be grown in a wide range of land from fertile to degraded or marginal soils and are the most important crops for the small and marginal farmers (Gowda et al., 2000; Schulz et al., 1999). These crops occupied about 11% of the country’s total cultivated land, and fourth in the area and production after rice, maize, and wheat (Darai et al., 2021; Neupane et al., 2021). Grain legume crops are also called ‘poor man’s meat’, and these crops have a significant role in increasing cropping intensity and crop diversification (Pokhrel and Poudel, 2024; Neupane & Shrestha, 2015; Bista et al., 2013). Among the grain legume crops, lentil (*Lens culinaris* Medikus), chickpea (*Cicer arietinum* L.; *Cicer kabulium.*), kidney bean/rajma (*Phaseolus vulgaris* L.), grasspea (*Lathyrus sativus* L*.*), fababean (*Vicia faba* L.), and field pea (*Pisum sativum* L.) are the main legume crops for the winter season. The Grain Legume Research Program (GLRP), Khajura is the only one research body under the Nepal Agricultural Research Council (NARC) of the country, which has mainly focused on improving food security, livelihood and resource conservation through the development of improved varieties, generating farmer's friendly technologies and providing consultative services (Maskey et al., 2001; Sharma, 2015). The GLRP has released and registered fourteen varieties of lentil, seven varieties of chickpea, and one variety of kidney bean for different agro-ecological domains with their improved cultivation practices, *i.e.*, agronomic and disease and pest management, but this program ~~has not been able to release~~ any variety of grasspea, fababean, and field pea dew to the human resources constraint. This coordinated paper certainly helps update the research status and strategies on winter grain legumes for all concerned researchers, extension personnel, students, and finally to the farmers.

**2. Area, Production and Yield of Winter Grain Legumes**

The lentil is the first important winter legume crop that is grown in 198,454 ha with the production and productivity of 252,283 t and 1.3 t/ha, respectively (MoALD, 2023). Similarly, chickpea and grasspea have grown in an area of about 10,600 ha, which have produced 12,143 t separately in the country. Among the grain legume crops, the lentil shares 59% of the total cultivated area, where chickpea and grasspea share about 3% of the cultivated area of grain legumes in the country. Not much data on the area and production of kidney beans are available in the country. Based on the MoALD (2023), the beans are grown in an area of 33,832 ha, which produces 40,260 t with a productivity of 1.2 t/ha.

There is an increasing trend in area, production and yield of lentil, chickpea and grasspea over 20 years in the country. The area of lentil, chickpea and grasspea has increased by 6, 3 and 34%, respectively in the year 2012/13-2021/22 as compared to the year 2003/04-2011/12. Similarly, the production of lentil (42%), chickpea (32%) and grasspea (92%) and also the productivity of lentil (33%), chickpea (25%) and grasspea (49%) has increased in the year2012/13-2021/22 compared with the year 2003/04-2011/12 (MoALD, 2012 and 2023). The annual growth rate of area, production and productivity in all the winter crops has ranged from 0.4% to 2.1%, and followed the positive trends in all the crops. This is due to the area expansion of the crops and adaptation of improved varieties and production practices developed by GLRP. Moreover, Lentil, chickpea and grasspea are the major legume crops of the Madesh and Lumbini, where more than 73%, 65% and 63% of the area of these crops are recorded, respectively (MoALD, 2912 and 2023). Similarly, Dang, Kailali, Rautahat, Bara and Siraha are the top five lentil growing districts; Banke, Siraha, Kanchanapur, Saptari and Bardiya are the top five chickpea growing districts, while Nawalparasi west, Sarlahi, Parsa, Arghakhanchi and Morang are the top five grasspea growing and producing districts in the Napal. Moreover, Nepal ranks 7th and 5th in terms of area and production of lentil, respectively, in the world (FAOSTAT, 2023).

Table 1. Area, production and yield of winter grain legumes in Nepal

|  |  |  |  |
| --- | --- | --- | --- |
|  | Lentil | Chickpea | Grasspea |
| Harvested area (ha) |  |  |  |
| 2003/04-2011/12 | 193,221 | 9,527 | 7,117 |
| 2012/13-2021/22 | 205,095 | 9,834 | 9,514 |
| Percentage change | 6 | 3 | 34 |
| Annual growth rate (%) | 1.2 | 0.4 | 1.1 |
| Production (t) |  |  |  |
| 2003/04-2011/12 | 172,595 | 8,082 | 5,869 |
| 2012/13-2021/22 | 245,048 | 10,685 | 11,295 |
| Percentage change | 42 | 32 | 92 |
| Annual growth rate (%) | 2 | 2 | 1 |
| Yield (kg/ha) |  |  |  |
| 2003/04-2011/12 | 890 | 848 | 808 |
| 2012/13-2021/22 | 1,184 | 1,064 | 1,200 |
| Percentage change | 33 | 25 | 49 |
| Annual growth rate (%) | 2.1 | 0.9 | 2.1 |

Source: MoALD, 2012 and 2023.

Figure 1. Trends of area cultivated of major winter legume crops in Nepal (Source: MoALD, 2012 and 2023)

Figure 2. Area shares (in %) of grain legume crops in Nepal (Source: MoALD, 2023)

Table 2. Area and its percentage distribution of the winter legumes in provinces of Nepal

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SN | Province | Lentil, ha | Chickpea, ha | Grasspea, ha |
| 1 | Koshi | 14987 (8%) | 764 (7%) | 1060 (10%) |
| 2 | Madhesh | 81332 (41%) | 3411 (32%) | 2401 (23%) |
| 3 | Bagamati | 3574 (2%) | 659 (6%) | 489 (5%) |
| 4 | Gandaki | 5038 (3%) | 263 (2%) | 121 (1%) |
| 5 | Lumbini | 64195 (32%) | 3549 (33%) | 4191 (40%) |
| 6 | Karnali | 3098 (2%) | 1182 (11%) | 887 (9%) |
| 7 | Sudurpashchim | 26230 (13%) | 965 (9%) | 1259 (12%) |

Source: MoALD, 2023.

Table 3: Top ten winter legumes growing districts of Nepal

|  |  |  |  |
| --- | --- | --- | --- |
| Rank | Lentil (ha) | Chickpea (ha) | Grasspea (ha) |
| 1 | Dang (25,323) | Banke (1,368) | Nawalparasi west (2,711) |
| 2 | Kailali (20,069) | Siraha (1,255) | Sarlahi (855) |
| 3 | Rautahat (17,253) | Kanchanpur (827) | Parsa (631) |
| 4 | Bara (14,994) | Saptari (780) | Arghakhanchi (607) |
| 5 | Siraha (13,055) | Bardiya (690) | Morang (567) |
| 6 | Bardiya (13,013) | Surkhet (555) | Bajhang (505) |
| 7 | Saptari (10,020) | Dang (377) | Rautahat (456) |
| 8 | Parsa (9,766) | Salyan (360) | Kapilbastu (355) |
| 9 | Banke (9,550) | Jhapa (351) | Jhapa (285) |
| 10 | Sunsari (6,625) | Kapilbastu (350) | Surkhet (277) |

Source: MoALD, 2023.

Table 4. Top lentil producing country of the world

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Rank | Country | Area in thousand, ha | Production in thousand, t | Productivity, kg/ha |
| 1 | Canada | 1715 | 2301 | 1341 |
| 2 | India | 1412 | 1269 | 899 |
| 3 | Australia | 575 | 1000 | 1738 |
| 4 | Turkey | 343 | 445 | 1299 |
| 5 | United States of America | 244 | 249 | 1022 |
| 6 | Russian Federation | 217 | 258 | 1189 |
| 7 | Nepal | 198 | 252 | 1271 |
| 8 | Bangladesh | 144 | 191 | 1320 |
| 9 | Kazakhstan | 143 | 146 | 1019 |
| 10 | Iran (Islamic Republic of) | 132 | 77 | 580 |
| 11 | Ethiopia | 93 | 135 | 1456 |
| 12 | Syrian Arab Republic | 81 | 27 | 327 |
| 13 | China | 65 | 167 | 2570 |
| Southern Asia | | 1894 | 1793 | 947 |
| World | | 5504 | 6656 | 1209 |

Source: FAOSTAT, 2023.

**3. Import and Export Situations of Winter Grain Legumes in Nepal**

The national imports of grain legumes was found 147759 t with a net import value of 15005 million NRs that contributed 9% to the total import value of agricultural commodities in the country. Similarly, the winter legumes like lentil, chickpea and kidney bean contributed more than 70% and 64% in the total import quantity and value of the legume commodities. Despite the imports, lentil is an important and potential exportable commodity in the country. Moreover, lentil worth of 569 million NRs was exported from the country, where the contribution of total legume commodities to the total national agricultural commodities was found to be more than 4% (DoC, 2023).

Table 5. Import and export situations of winter grain legumes and their share in Nepal

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Commodity | Import |  | Export |  |
| Quantity, t | Value, Million NRs | Quantity, t | Value, Million NRs |
| Lentil | 52508 | 5105 | 3908 | 569 |
| Chickpea | 47011 | 4050 | 43 | 8 |
| Kidney bean | 4080 | 480 | 3 | 0.6 |
| Total winter legume | 103599 | 9635 | 3954 | 578 |
| Total legume crop | 147759 | 15005 | 4092 | 609 |
| Percentage of the winter legumes to the total legume | 70.1 | 64.2 | 96.6 | 94.8 |
| Percentage of the total legume commodities of the total agricultural commodities |  | 9.4 |  | 4.0 |

Source: DoC, 2023.

**4. Multi-location trial sites for generating the technology of GLRP**

Grain Legumes Research Program, Banke has been collaborating with the different research directorates/centers/commodity programs/stations of the NARC, i.e., Directorate of Agricultural Research (Koshi Province), Sunsari, Jute Research Program, Sunsari, Agricultural Research Station, Dhankuta, Directorate of Agricultural Research (Madhesh Province), Bara, Oilseed Research Program, Sarlahi, Agricultural Research Station, Dhanusha, Hill Crop Research Program, Dolakha, [National Agronomy Research Centre](https://narc.gov.np/agronomy/), Lalitpur, [National Plant Pathology Science and Research Centre](https://narc.gov.np/agronomy/), Lalitpur, [National Plant Breeding and Genetic Research Centre](https://narc.gov.np/agronomy/), Lalitpur, Directorate of Agricultural Research (Gandaki Province), Kaski, Horticultural Research Station, Kaski, Horticultural Research Station, Dailekh, Agricultural Research Station, Jumla, Directorate of Agricultural Research (Karnali Province), Surkhet, Ginger Research Program, Salyan and Directorate of Agricultural Research (Far Western Province), Doti, for developing the technologies of grain legumes in the country.

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Figure 3. Multi-location testing sites of GLRP ()

**5. Research Accomplishments in Winter Legumes**

**5.1 Lentil**

More than 100 genotypes of lentil are under evaluation in different trials. Fourteen varieties of lentil have been released and recommended for general cultivation in various geographical locations in the country, and genotypes PL 4, ILL 7979 and HUL 57 are selected as promising lines. Similarly, 207 germplasms of lentil are conserved in the gene bank of NARC (Pokhrel and Poudel, 2024).

Table 6. Recommended and promising varieties and their characteristics of lentil

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SN | Variety | Origin | Released year, BS | Recommended domain | Crop duration | Productivity | Special character |
| Recommended variety | | | | | | | |
| 1 | Sindur | Nepal (LO-1110-25) | 2036 | Terai to hills | 145 | 1.5 | Wide adaptation |
| 2 | Shishir | India (P 43) | 2036 | -do- | 150 | 2.0 | -do- |
| 3 | Simrik | India (T 36) | 2036 | -do- | 143 | 1.5 | Medium bold seeded, wilt tolerance |
| 4 | Simal | India (LG 7) | 2046 | -do- | 143 | 4.1 | Small seeded |
| 5 | Shikhar | Pakistan (ILL 4404) | 2046 | -do- | 143 | 3.5 | Wilt tolerance |
| 6 | Khajura Masuro 1 | India (LG198) | 2056 | Mid to far western terai | 128 | 1.5 | -do- |
| 7 | Khajura Masuro 2 | ICARDA (PL 639) | 2056 | -do- | 134 | 2.1 | Bold seeded, wilt tolerance |
| 8 | Shital | ICARDA (ILL 2580) | 2061 | Terai to hills | 134 | 1.1 | Wilt tolerance |
| 9 | Maheswor Bharati | ICARDA (ILL 7982) | 2064 | Kathmandu valley and river basins | 111 | 1.4 | Bold seeded, wilt tolerance |
| 10 | Sagun | ICARDA (ILL6829) | 2064 | -do- | 98 | 1.3 | -do- |
| 11 | Khajura Masuro 3 | Nepal (RL 4) | 2073 | Terai to river basins of hills | 145 | 1.5 | Tolerant to stemphylium blight |
| 12 | Khajura Masuro 4 | ICARDA (ILL 7723) | 2075 | Mid to far western terai | 136 | 1.1 | Tolerant to wilt and stemphylium blight |
| 13 | Shraddha Kalo Masuro | Nepal (Black lentil) | 2075 | Terai to hills | 142 | 1.3 | Tolerant to wilt and stemphylium blight, good test |
| 14 | Rasuwa Kalo Masuro | Nepal (Black lentil) | 2075 | Rasuwa (1800-2500 masl of eastern hills) | 150 | 1.3 | Brand of Rasuwa, good test |
| Promising varieties | | | | | | | |
| 1 | ILL 7979 | Special character: short duration, tolerance to high soil moisture, tolerance to stemphylium blight, medium in yield | | | | | |
| 2 | PL 4 | Special character: short duration, bold seeded, tolerance to stemphylium blight, zinc-rich | | | | | |
| 3 | HUL 57 | Special character: short duration, bold seeded, tolerance to stemphylium blight, selenium-rich | | | | | |

Source: Pokhrel and Poudel, 2024.

* Variety: early varieties.
* Seed rate: 40 kg/ha.
* Planting spacing: 25 cm × continuous.
* Seed treatment: Bevistin (Carbendazim) @ 2.5 g/kg seed.
* Seeding time: Earlier, 2nd week of October (within *Asoj* month),
* Cropping systems: Early maturing rice variety (<125 days) – lentil.
* Seed priming: seed primed with water at 8 hours/seed primed with 250 ppm solution of Na2MoO4.
* Relay cropping: seeding seeds 15-20 days before harvesting of rice at the foot print soil moisture condition.
* Mixed/inter cropping: seed of lentil:rapeseed @ 30:2 kg/ha/20:6 kg/ha or 2:2 line.
* Seed treatment: treated seeds with *R. leguminosarum* @ 5 g/kg seed.
* Fertilizer: 20:40:20 kg NPK/ha/4.3 kg DAP, 1.7 kg Potash and 0.5 kg Urea/ropani; in fertile soil 4.3 kg DAP and 1.7 kg Potash.
* Weed management: mulching with rice straw/two-hand weeding at 25 and 45 DAS/use of pendimethalin 30 % EC @ 3-4 ml/liter of water at a DAS.
* Irrigation: light irrigation before flowering time.
* Stemphylium blight: Saff (carbendazim + mancozeb) or clorothalonil @ 2.5 g/liter water spray at one-week interval.

**5.2 Chickpea**

More than 100 genotypes of chickpea are under evaluation in different trials. Though, seven varieties of chickpea have been released and recommended for general cultivation various geographical locations in the country, among them one variety ‘Trishul’ has been de-notified due to its production constraints like wilting susceptibility. Likewise, genotypes ICCV 97207, KPG 59 and ICCX 840508-31 have been selected as promising lines, among the tested genotypes in different trials of GLRP.

Table 7. Recommended and promising varieties and their characteristics of chickpea

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SN | Variety | Origin | Released year, BS | Recommended domain | Crop duration | Productivity | Special character |
| Recommended variety | | | | | | | |
| 1 | Dhanush | Nepal | 2036 | Terai and inner terai | 144 | 1.8 | Drought tolerance |
| 2 | Radha | India (JG 74) | 2044 | -do- | 142 | 1.6 | -do- |
| 3 | Sita | ICRISAT (ICC 4) | 2044 | -do- | 140 | 1.5 | -do- |
| 4 | Kalika | ICRISAT (CL  82108) | 2047 | Mid to far western terai and inner terai | 153 | 1.4 | Suitable for mid-western terai |
| 5 | Kosheli | ICRISAT (ICC 32) | 2047 | -do- | 154 | 1.6 | Suitable for mid to far-western terai |
| 6 | Tara | Nepal (ICCX  840508 -36 | 2064 | Terai to hills | 135 | 1.4 | -do- |
| 7 | Avrodhi | India  (Avrodhi) | 2064 | -do- | 135 | 1.3 | Suitable for mid-western terai |
| Promising varieties | | | | | | | |
| 1 | ICCV 97207 | Special character: bold-sized seed, tolerance to wilting and blight | | | | | |
| 2 | KPG 59 | Special character: medium-size seed, tolerance to wilting and blight | | | | | |
| 3 | ICCX 840508-31 | Special character: early duration, bold seeded, tolerance to blight | | | | | |

* Seed rate: 40 (small-seeded) to 60 (bold-seeded) kg/ha.
* Planting spacing: 40 cm × 7-10 cm
* Seed treatment: bevistin (Carbendazim) @ 2.5 g/kg seed.
* Seeding time: 1st to 2nd week of November (within 3rd and 4th week of *Kartik* month)
* Seed priming: seed primed with water at 8 hours/2% solution of calcium sulphate (CaSO4).
* Mixed/inter cropping: seed of chickpea:linseed @ 2:1 line, chickpea:rapeseed @ 4:2 line.
* Seed treatment: treated seeds with *R. mexcellany* (cowpea)@ 5 g/kg seed.
* Fertilizer: 20:40:20 kg NPK/ha/4.3 kg DAP, 1.7 kg Potash and 0.5 kg Urea/ropani; in fertile soil 4.3 kg DAP and 1.7 kg Potash.
* Weed management: Mulching with rice straw/two-hand weeding at 25 and 45 DAS/use pendimethalin 30 % EC @ 4 ml/liter of water at a DAS.
* Irrigation: light irrigation before flowering time.
* Pod borer management: monitoring of insect population through the pheromone (helilure) traps, and application of HaNPV or Multineem @ 2.5–3 ml/liter water or Spinosad @ 0.5ml/liter water from the beginning of insect attack or inter/mixed crop with coriander helps to minimize the pod borer population. Use of yellow sticky traps or foliar spray of 50% Chlorpyriphos and 5% Cypermethrin @ 2 ml/liter water helps to manage the insect population.
* Fusarium wilt and root or foot rot: Saff (carbendazim + mancozeb) or Bevistin (carbendazim) @ 2.5 g/liter water spray at one-week interval.
* Botrytis gray mold: Ronilan (vinclozolin) @ 2.5 g/liter water spray at one-week interval.

**5.3 Kidney bean**

The Grain Legumes Research Program has released only one variety of kidney bean in Nepal and genotypes ‘Arun’ and ‘Chitra’ are identified as the promising varieties from the trials conducted in different locations of Nepal.

Table 8. Recommended and promising varieties and their characteristics of kidney bean

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SN | Variety | Origin | Released year, BS | Recommended domain | Crop duration | Productivity | Special character |
| Recommended variety | | | | | | | |
| 1 | PDR 14 | India (PDR 14) | 2075 | Terai to mid hills | 144 | 1.8 | Tolerance to anthracnose and white mould |
| Promising varieties | | | | | | | |
| 1 | Arun | Special character: early maturing and attractive seed coat color | | | | | |
| 2 | Chitra | Special character: early maturing and attractive seed coat color | | | | | |

* Sowing time: last week of October or with early maturing rice–rajma cropping system.
* Seed rate: 90 – 100 kg/ha.
* Planting spacing: narrow row spacing seemed better than the wider row/40–50 cm × 10 cm.
* Fertilizer: 5 t FYM/ha plus chemical fertilizers @ 100:60:40 kg N:P2O5:K2O/ha.
* Weed management: mulching with rice straw; two-hand weeding at 25 and 50 DAS followed by ridging.
* Disease management: seed treatment with Captan @ 2 g /kg; 3 times foliar spray of Copper oxychloride @ 2 g/liter water from the onset of white mould appearance at 7 days intervals.

**5.4 Grasspea**

Nepalese grasspea land races generally contained high (0.6 to 0.8 % of the acid ODAP) neurotoxin–β-*N*-oxalyl-l-α,β-diaminopropionic acid (β-ODAP), therefore, it is most important to develop the low ADOP (0.01 to 0.02 % ODAP) containing grasspea varieties that are safe for human and animal health.

* The low ODAP containing grasspea genotypes, Bidhan-1 Ratan and GP-97 found better genotypes in terms of their yield.

**6. Research Strategies of GLRP for Generating Technologies for Winter Legumes**

**6.1 Short term**

* Collection of local materials of winter legumes and segregating materials from International Agricultural Research Centers (IARCs) for evaluation, selection and recommendation of varieties.
* Identification of the sources of resistance for major diseases and pests.
* Identification of the major problems of winter legumes production in farmer’s field.
* Verification of the on-station proven technologies in farmer’s field.

**6.2 Long term**

* Strengthen breeding program, *i.e.* molecular breeding, developing early maturing heat and water logging stress tolerance, micronutrient rich varieties.
* Crop simulation modeling on pulses to predict the crop production and sustainable use of water.
* Research in integrated pests and diseases management.
* Initiate research on postharvest management and value addition.
* Initiate research on cropping systems and residue management.
* Develop nutrient loading, weed management and climate resilience technologies.
* Standardize the foliar spray of urea for balanced nutrition.
* Production and supply of breeder and foundation seeds.
* Collaborative research works with other national and international research organizations/institutes/centers.

**7. Collaboration**

The 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,Syria) for lentil, kabuli type chickpea, grasspea, fababean; International Crops Research Institute for the Semi-Arid TroFs (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: RARSs, ARSs and disciplinary divisions of NARC for technologies evaluation, verification and germplasm conservation; Seed Quality Control Centre (SQCC) for variety release; agricultural offices for technologies transfer. Similarly, the GLRP works with the different NGOs, farmer groups/cooperatives, and seed companies for the dissemination of technologies at the farm level.

**8. Conclusion**

The GLRP in collaboration with various national and international agricultural research organizations has led to the release and recommendation of fourteen varieties of lentil, seven varieties of chickpea and one variety of kidney bean with their appropriate cultivation/production technologies ultimately resulting into a substantial increase in lentil, chickpea and grasspea production (42, 32 and 92 percent, respectively) and productivity (33, 25, 49 percent, respectively) in the country.

**COMPETING INTERESTS DISCLAIMER:**

**Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.**

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