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Full length Research paper

Assessment of wheat seed quality collected from various sources (formal and informal) in Nepal

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The low quality of wheat seed used as farmer protected seed is a crucial factor in reducing the average productivity of wheat. So, this research was conducted at AFU, Rampur, Nepal, from Nov 2017 to Jan 2018 to find out the quality status of farmer preserved seed and seeds of the formal sectors. Survey and sample collection carried out from National Wheat Research Program (NWRP) Bhairahawa, Unnat Bijbriddi Seed Company, Patihani, and farmers of three districts, respectively, from Chitwan, Bardiya, and Baglung. The laboratory experiment was done in CRD design. The physical purity was higher in seeds from the formal source (>99%); however, the physiological quality was inconsistent. Among all sources, NWRP provided the best seed germination (95 ± 1.79 %), and seed vigor index (SVI) (1389 ± 59.54). Yet, another official source, i.e., Seed Company, showed significantly poor germination (57 ± 7.21 %), and SVI (542 ± 153.84). Besides, some farmers' samples showed very low seed germination (<1%) and SVI. As the farmers' seeds from Baglung district have significantly higher germination (73 ± 3.52 %) & SVI (929 ± 53.47), the production and storage of wheat seed in Baglung or similar ecology might have a higher potentiality to maintain good physiological quality. Thus, it is asserted that, when farmers' seed has acceptable quality, it can be an excellent choice to use their own saved seed. Otherwise, to avoid massive loss due to poor seed quality, one can choose to go with the formal seed.

Keywords: Seed, quality, source, wheat, germination.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the predominantly cultivated cereals in the world as well as in Nepal. The demand for wheat is rising substantially because of the increasing population. China is the top producer of wheat (133 million tons), followed by India (102 million tons), Russia (74 million tons), and then by the United States (52 million tons) (Statista, 2020). The global average productivity of wheat was 3.47 t ha^{-1} in the year 2017/18; however, European union produced with an average of 5.8 t ha^{-1} (USDA, 2019). In Nepal, the area under wheat was 753 thousand ha in the previous year, and production was 1811 thousand metric tons with a productivity of 2.40 t ha^{-1} (AICC, 2019). Commonly clean and healthy seeds with proper moisture, functional germination capacity, and the high seed vigor are said quality seeds. The difference in seed quality between farmers' seed and certified seed is mainly due to the presence of impurities (Bishaw, Struik, & Van Gastel, 2012). The seed size varies with genotype under the same practice, and larger seeds have higher germination percentage, seedling weight, seedling vigor, and seedling length of the same variety (Farahani, Moaveni, &Maroufi, 2011; Shahwani et al., 2014). Usually, farmers' seeds have low thousand-grain weight in comparison with certified seeds (Khan, Khan, Khan, Ghoneim, &Ebid, 2007; Kshetri, 2010). The inappropriate moisture level is one of the major causes of post-harvest seed damage during seed storage. Previous researchers found that formal seed has higher seed germination in comparison with farmer's seed (Joshi et al., 2016; Khan et al., 2007). But, in some cases, formal seed provided by the government was found inferior to the informal seed of local trader in the performance of germination (Bishaw et al., 2012). In certified seeds, better vigor indices found while comparing with farmers' seed (Abati, Brzezinski, Zucareli,

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Foloni, & Henning, 2018; Bishaw et al., 2012; Jama, Hasan, Mohamed, Addow, & Roble, 2018). While considering seed health, *Bipolaris spp* and *Alternaria spp* found to be serious seed-borne pathogens in wheat seed (Burlakoti, Shrestha, & Sharma, 2014; French, 2015; Morejon, Moraes, & Bach, 2006; Siddique, Rashid, Hossain, Khalequzzaman, & Uddin, 2002). The infection of *Bipolarissorokiniana* and *Alternaria spp* was found minimum in certified seeds and high in farmers' seed (Kshetri, 2010). However, the informal seed is found superior over formal seeds in many cases. Some frauds in the legal seed sector mixed seed of low quality with high-quality seed in developing countries (Joshi, Conroy, & Witcombe, 2012). On the other hand, a farmer can produce seeds having quality status analog with certified seeds (Kshetri, 2010) so that the quality of farmers' seed in comparison with certified seed is questionable in developing countries like Nepal.

Generally, farmers are suggested not to plant their own saved seed because of lower quality than legal and certified seeds. However, the use of own saved seeds to produce wheat is widespread across the world. Among the various factors, poor seed quality plays a vital role in reducing the yield of wheat (Tonu et al., 2017).

The unavailability of an adequate amount of quality seeds at the right time and place stands as a primary constraint in improving the yield and economic status of Nepalese farmers (Adhikari, 1999; SQCC, 2013). It is also possible that providing the certified seed instead of farm-saved seed to farmers is not economical always (Khazaei et al., 2016).

The Seed Vision 2013-25 reported inadequate access to quality seeds, poor knowledge on seed use, and low coverage of formal seed system (<10%) are major constraints of seed sector development in Nepal. Also, current research and extension services and public support measures are inadequate, which are poorly targeted and ineffective in meeting the quality seed needs of chosen variety to the farmers.

Therefore, it is necessarily a great need to conduct researches related to seed production and consumption for seed sector development in Nepal, and a similar solution has been reported by Gauchan (2017) for seed sector development. Thus, this research was done to evaluate the quality status of seed collected from various formal and informal sources and to suggest a better option to consumers.

METHODOLOGY

Weather data collection

The weather data were obtained from the record of Surface meteorology and Solar Energy (SSE) project preserved by NASA Power.

Study sites

Chitwan and Bardiya lie at the lower altitude; Chitwan has approx. 185 m altitude, 27.655^0 N latitude &84.356^0 longitudes and Bardiya has 153 m altitude, 28.271^0 N latitude & 81265 ^{0} E longitude. Chitwan lies in the central region of province three, and Bardiya lies in the far western region of province 5. While, Baglung lies at high altitude, approx. 1326 m altitude, 28.201^0 N latitude and 83.637^0 E longitude, which is geographically a hilly district and lies in the western region of Gandaki province. In addition to this, seeds collected from certified sources, i.e., Nepal Agriculture Research Council (NARC), National Wheat Research Program (NWRP), Bhairahawa, Rupendehi (110 m altitude, 27.56^0 N latitude and 83.437^0 E longitude) and Seed Company, Patihani, Chitwan (elevation and coordinates same as Chitwan).

Survey and sample collection

In all three districts, clusters of farmers dominated with wheat cultivation were selected. Amongst them, farmers using their own saved seed were selected for a short interview and seed collection purposively. Based on population size, thirty-two farmers from Chitwan, thirty-two farmers from Bardiya, and twenty-seven farmers from Baglung districts were interviewed, and seeds were collected from them. Additionally, four samples were taken from NARC, NWRP, Bhairahawa, Rupendhehi, and three samples were taken from Seed Company, Patihani, Chitwan as certified sources. Sampling and sub-sampling of seed samples were done using Boerner divider. After sampling, seeds were stored in a air-tight plastic storage bag and taken for the test in laboratory.

Seed testing

The individual sample was tested for purity, thousand seed weight, and moisture content in Seed Laboratory, Department of Agronomy, Agriculture and Forestry University (AFU), Rampur. The germination and seedling characteristics were tested in Regional Seed Testing Laboratory (RSTL), Hetauda, and seed health was tested in the Department of Plant Pathology, AFU, Rampur. Standard rules and methods were followed to test each quality parameter as described in National Seed Testing Directives 2017 (SQCC, 2017). The lab experiment was done under CRD design with one replication for the purity test, two replications for seed moisture content, four replications for germination and seedling characteristics, and again four replications for seed health test and thousand seed weight.

Purity test

The purity test was done in the seed laboratory of AFU, Rampur. A working sample of Wheat was drawn from the collected sample, weighed and recorded in grams, corrected to three decimals. Then it was then placed over

the purity analysis board. The sample was separated by using forceps and hand lens into four components: the pure seed of wheat, seed other species, weed seeds, and inert matters. Individual data recorded for all these parameters.
The purity percentage of the given sample was calculated using the following formula,

$$\text{Purity \%} = \frac{\text{Weight of pure seed in g}}{\text{Weight of sample in g}} \times 100\ \%$$

$$\text{Inert matter \%} = \frac{\text{Weight of inert matter in g}}{\text{Weight of sample in g}} \times 100\ \%$$

$$\text{Other crop seed\%} = \frac{\text{Weight of other crop seed in g}}{\text{Weight of sample in g}} \times 100\ \%$$

$$\text{Weed seed \%} = \frac{\text{Weight of weed seed in g}}{\text{Weight of sample in g}} \times 100\ \%$$

Germination test

The count of 400 seeds done without discrimination as to size or appearance using hand. By soaking and setting, the excess moisture germination paper was prepared for substratum. Then seeds are plated on a layer with enough space to allow aeration and gas exchange for producing healthy seedlings. Finally, the germination chamber was set for required conditions as for the plated seeds, i.e., 90% RH and 20^0C. During observations, normal seedling, abnormal seedling, and dead seeds were counted.

Seed moisture test

At first, the empty aluminum-can was weighed with its cover. Then seed was ground evenly using a grinder mill. The ground product was mixed well, and 5 g of ground sample was taken on a weighed can. After weighing the sample with can, the gerund flour was distributed evenly on the bottom of the containers. Then can was placed inside an oven, heated to $105\text{-}106^0$ C temperature, for 18 hours. At the end of the seed drying period, aluminum-can was taken out, closed with its cover, and transferred to desiccators having silica gel. After 40 to 45 min, it was taken out and weighed again. The moisture content of seed was calculated using the following formula;

$$\text{Seed moisture content (\%)} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where,
M_1 = Weight of the weighing can/container with cover in g.
M_2 = Weight of the weighing can/container with cover and seeds before drying
M_3 = Weight of the weighing can/container with cover and seeds after drying.

Root length and shoot length

The 20 normal seedlings were randomly selected from each sample, and the shoot length was measured from cotyledon to the tip of the seedling. The root length was measured from cotyledon to the tip of the root. The average shoot or root length was calculated by dividing the total shoot or root lengths by the total number of normal seedlings measured. As per Khazaei et al. (2016), the seedling shoot and root lengths were assessed after the final count.

Seedling vigor index

The seedling vigor index (SVI) for each replication was calculated by using averaged root length and shoot length of that replication and germination percentage. The following formula calculated it;
SVI = (Rl + Sl) x G%
Note: SVI = Average seedling vigor index; Rl = Root length; Sl = Shoot length; G% = Germination percentage

Seed health test

The study was targeted for *Alternaria spp* and *Bipolaris spp*. At first, all the equipment (forceps, blotter paper, Petri-plates) were autoclaved for sterilization at 15 psi and 121^0C. Then the working hand and working place were surfaces sterilized by 99% alcohol. Then all the plates were arranged on sterilized laminar flow to place seeds on each plate. Blotter paper was first soaked on distilled water and removed excess water from them before putting them on Petri-plate. Three-layer of blotter paper were placed on each 9 cm Petri-plate, and 25 seeds of different sources were placed on each Patri-plate with the help of forceps. These plates were incubated for seven days under alternate light and dark conditions under 21^0C and 90% RH. Observation and count of infected seed were done on the 7^{th} day of incubation. Seeds from the seed company were treated with fungicides, so these seeds did not proceed for the health test.

Statistical analysis

Test of normality and multiple comparisons was done using r-studio; descriptive and frequency statistics were calculated using IBM-SPSS; and correlation, regression, frequency, means, and graphs were made using Microsoft Excel. Data abnormal with P value less than 0.05 were projected to the Kruskal-Wallis test (probability adjusted with Bonferroni) followed by multiple comparisons of rank, and normal data with P value less than 0.05 were projected to Duncan Multiple Range Test (DMRT) for mean comparison.

RESULTS

Weather parameters of study sites during the cultivation and storage period

During the early crop growth period, all areas were cold and dry until 70 days of the year 2017. In Bardiya and Bhairahawa, weather was hot and dry from 70 days to 170 days, whereas in Chitwan weather was warm and dry till 70 days to 140 days; however, in Baglung, weather was relatively cooler and dry from 70 days to 150 days of the year 2017. After that, the weather became hot and humid until October at Bardiya, Bhairahawa, and Chitwan. But the weather of Baglung was cold and moist during that time.

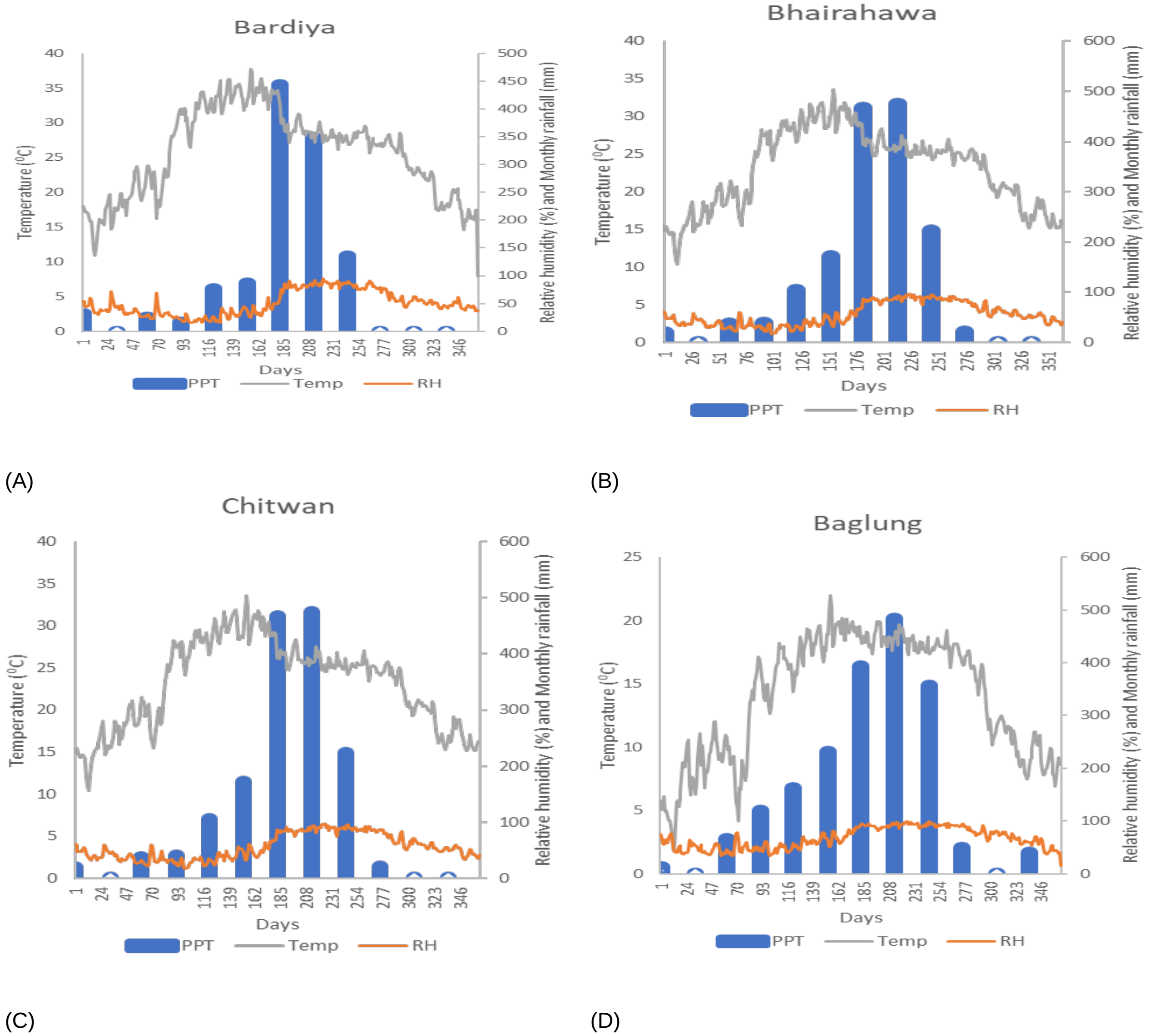
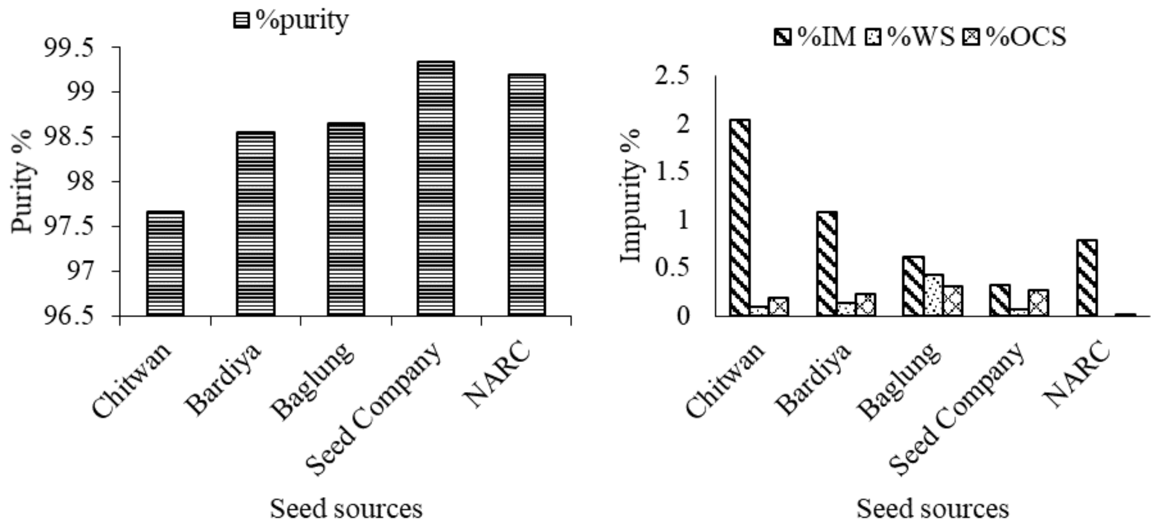


Figure 1: Temperature (^{0}C), Relative humidity (%) and Monthly rainfall (mm) of different study sites during production and storage period of wheat, 2017/18

Note: PPT: Precipitation/Rainfall, Temp: Temperature, RH: Relative humidity

Physical purity

Physical purity of seed was at par (99%) in the formal seeds collected from the seed company and NWRP, NARC, while the farmers' own saved seeds had low physical purity (Figure 2). Among farmer saved seeds, seeds collected from Chitwan had the lowest purity percentage (97.5%), whereas seeds from Bardiya and Baglung had approximately 98.5% purity. The maximum percentage of inert matter (impurities) was in farmers' seed from Chitwan (2%) and lowest in seeds collected from the seed company (<0.4%). Other crops



(A) (B)

Figure 2: Seed purity (%) (A) and impurities in seed (%) by weight (B) in seed collected from various seed supply sources, 2017/18
Note: IM: Inert matter; WS: Weed seeds; OCS: Other crops seeds

seed and weed seed were lowest in the formal seed from NWRP, NARC. The highest other crop seed and weed seed were recorded in farmers' seed obtained from Baglung.

Germination percentage, Normal seedling, abnormal seedling, and Un-germinated seed

Formal seed collected from NWRP, NARC had the highest germination (95%) followed by farmers' seeds collected from Baglung (73%), and Bardiya (66%). Formal seed obtained from seed company had the lowest germination (57%) followed by farmers' seed from Chitwan (59%). In total legal seed from NWRP, NARC yielded significantly higher germination percent than other formal and informal sources. Whereas Seeds from the seed company, farmers of Bardiya, and farmers of Chitwan produced statistically similar germination percent but significantly lower than that of farmers' seed from Baglung.Among informal sources, farmers' seed from Baglung gave the highest germination percentage. There was a significant variation in the normal seedling count. The normal seedling count was highest in the formal seed from NWRP, NARC (92%), and was statistically superior over all other remaining sources. Among farmers' categories, seed collected from Baglung produced the highest number of normal seedling (66%). The lowest count of normal seedling was observed from the formal seed of seed company (45%) followed by farmers' seed from Chitwan. The lowest abnormal seedling was found in the formal seed collected from NWRP, NARC (3%), and the count was significantly lower than the abnormal seedling count of all other remaining formal and informal seed categories. Where all the different seed categories except the seed collected from NWRP, NARC yielded statistically similar abnormal seedlings (Table 1). The un-germinated seed was statistically higher in the certified seed of seed company as compared with certified seeds from NWRP, NARC, and farmers' seed from Baglung. The maximum number of un-germinated seed was recorded in seeds collected from the seed company (43%), which was at par with farmers' seed from Chitwan and Bardiya but significantly higher than that of farmers' seed from Baglung and formal seed from NWRP, NARC (Table 1). Seeds collected from NWRP, NARC yielded the lowest number of un-germinated seeds (5%).

The range of germination percentage and seed vigor index varied greatly among various sources (Figure 3). In three categories excluding formal seed from the seed company, maximum germination percent was recorded 100%. However, the minimum germination percent was recorded 0 % in two farmers' categories, i.e., in seeds collected from farmers of Chitwan and Bardiya. So minimum germination percent of farmers' seed was found 0%, but in the formal seed minimum germination percent was greater than 20%.

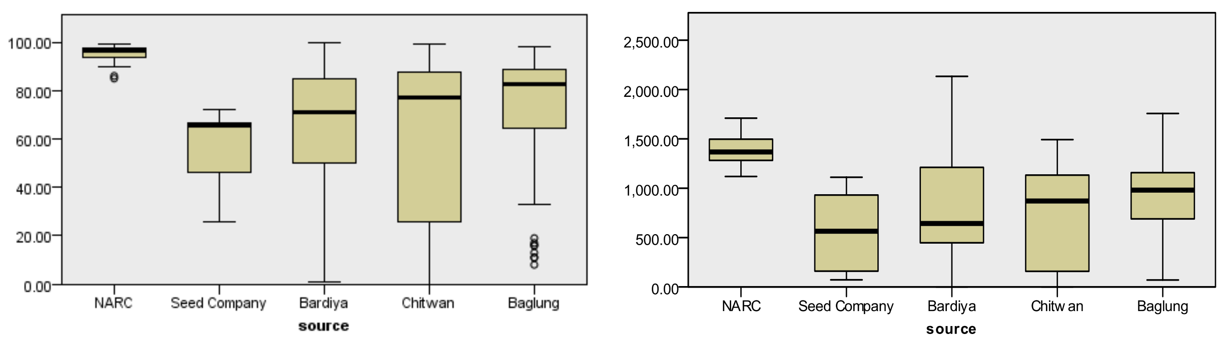
Radicle length, plumule length, seed vigor index and thousand seed weight

The length of the radicle was found to vary significantly amongst various seed sources. Formal seed from NWRP, NARC produced the most extended radicle length (10 ± 0.71), whereas another formal seed from seed company produced the shortest radicle (7 ± 1.38 cm). All the farmers' seeds produced radicle length

Table 1: Mean comparison of germination percent, normal seedling count, abnormal seedling count, and un-germinated seed count of the wheat seeds collected from various sources (using Kruskal-Wallis test), 2017/18

Source of seed	Germination	Normal Seedling Count	Abnormal Seedling Count	Un-germinated Seed Count
NWRP, NARC	95 ± 1.79 A	92 ± 1.79 A	3 ± 0.55 B	5 ± 1.50 C
Seed company	57 ± 7.21 C	45 ± 7.21 C	13 ± 3.15 A	43 ± 6.94 A
Farmers' seed Bardiya	66 ± 3.28 BC	56 ± 3.28 BC	10 ± 0.85 A	34 ± 3.04 AB
Farmers' seed Chitwan	59 ± 4.17 C	52 ± 4.17 C	7 ± 0.64 A	41 ± 4.37 A
Farmers' seed Baglung	73 ± 3.52 B	66 ± 3.52 B	8 ± 0.78 A	27 ± 3.35 BC

Note: Means in the column followed by the same letter(s) are not significantly different below P = 0.05



(A)(B)

Figure 3: Distribution of germination percentage (A) and seed vigor index (B) among various sources, adopted from lab experiment 2017/18

significantly lower than that of NWRP, NARC but statistically similar or superior to radicle length of formal seed from the seed company. Farmers' seeds from Baglung and Bardiya produced same radicle length but statistically longer than that of Chitwan (Table 2). Plumule length also varied significantly amongst different categories of seed. The longest plumule length was observed in the formal seed collected from NWRP, NARC (5 ± 0.17 cm), and lowest plumule length was observed in another formal seed collected from the seed company (4 ± 0.55 cm). Plumule length of farmers' seed from Baglung and formal seed from NWRP, NARC were at par, and both were superior over other formal and informal seed categories (Table 2). Thousand seed weight of the formal seeds obtained from NWRP, NARC, and seed company (both 54 g) were superior over farmers' seeds collected from Bardiya, Chitwan, and Baglung.

Farmers' seeds obtained from Bardiya and Chitwan had statistically similar thousand weights, but they were superior over farmers' seed obtained from Baglung and inferior to the thousand seed weight of formal seeds (Table 2).

The formal seeds taken from seed company had the lowest seed vigor index (542 ± 153.84) and seed taken from NWRP, NARC had the highest seed vigor index (1389 ± 59.54). Seeds taken from farmers of Baglung and Bardiya yielded an intermediate seed vigor index, higher than that of seeds collected from farmers of Chitwan and formal seed collected from the company. Seed collected from farmers of Chitwan and formal seed collected from seed company yielded statistically similar and low seed vigor index (Table 2).

Moisture content and Seed health test

The highest average moisture content was found in formal seeds collected from the seed company (15.14%), statistically higher than all other remaining sources.

All the farmers' categories have similar average moisture percentage, i.e., average moisture content ranging from 13.12% to 13.46% (Table 3). Lowest moisture was recorded in the formal seed from NWRP, NARC (12.22%), statistically lower than all other formal and farmers' categories.

The number of infected seed by *Bipolaris spp* and *Alternaria spp* was found to vary significantly among various sources. Farmer' seed collected from Baglung had *Bipolaris spp* infection (1.25 out of 25 seeds infected) considerably lower than that of seed obtained from Bardiya and Chitwan but was at par with formal seed collected from NWRP, NARC, shown in Table 3; While the number of seed infected with *Alternaria spp* was found significantly higher in farmers' seeds collected from Baglung (14 out of 25 seeds infected). Infection of *Alternaria* in farmers' seed of Bardiya & Chitwan and seed collected from NWRP, NARC were

Table 2: Mean comparison of radicle length, plumule length, seed vigor index and seed size of the wheat seeds collected from various sources (using Kruskal-Wallis test), 2017/18

Source of seed	Radicle (cm)	Plumule(cm)	Seed Vigor Index	TSW (g)
NWRP, NARC	10 ± 0.71 A	5 ± 0.17 A	1389 ± 59.54 A	54 ± 0.77 A
Seed company	7 ± 1.38 C	4 ± 0.55 B	542 ± 153.84 C	54 ± 1.19 A
Farmers' seed Bardiya	9 ± 0.36 BC	4 ± 0.16 B	786 ± 65.59 BC	48 ± 0.65 B
Farmers' seed Chitwan	8 ± 0.46 C	4 ± 0.23 B	730 ± 63.14 C	49 ± 0.43 B
Farmers' seed Baglung	9 ± 0.26 B	5 ± 0.15 A	929 ± 53.47 B	44 ± 0.80 C

Note: Means in the column followed by the same letter(s) are not significantly different below P = 0.05

Table 3: Mean comparison of seed moisture content (%) and infected seed count (out of 25 seeds) in the wheat seeds collected from various sources, (using Duncans' Multiple Range test), 2017/18

Seed source	Moisture percentage	*Bipolaris spp*	*Alternaria spp*
NWRP, NARC	12.13^{c}	1.75^{b}	4.50^{b}
Seed companies	15.29^{a}	NA	NA
Farmers' seed Bardiya	13.47^{b}	5.00^{a}	5.00^{b}
Farmers' seed Chitwan	13.10^{b}	4.00^{a}	6.50^{b}
Farmers' seed Baglung	13.47^{b}	1.25^{b}	14^{a}
SEm (±)	0.13	0.729	1.04
LSD (=0.05)	0.35	2.24	3.20
CV%	10.60	28.60	27.80
Grand mean	13.34	3.00	7.50

Note: Means in the column followed by the same letter(s) are not significantly different below P = 0.05; NA: data not available

statistically similar (Table 3).

DISCUSSION

The quality of seed depends on various factors such as pre-harvest factors, harvesting, and post-harvest factors. During storage, deterioration is directly influenced by the storage environment (RH, Temperature, and Air), seed moisture, biotic agents, and duration of storage. The method, process, and time of storage depend on farmers' practice, so the quality of farmers' seed is unpredictable until the laboratory test.

From the test, high physical purity of seed was found in formal seeds of Seed Company and NWRP, NARC followed by farmers' seed categories (Figure 2). The superiority of certified seeds over farmers' seed in physical purity might be due to variation in seed processing techniques.

Seed Company and NWRP, NARC, usually follow mechanical harvesting and cleaning with modern technologies. Minimum impurities in NWRP, NARC, and seed company might be due to timely weeding and rouging with regular monitoring by technicians for seed production. In the districts of Terai (Chitwan and Bardiya), mechanical harvesting can be done, but the facility of automated processing is lacking, and in contrast to this, both automatic collection and processing are lacking in Baglung district. Such variation in harvesting method may be the reason behind the minimum purity percent found in Baglung, i.e., 94%.

Separation of chaffs, weed seed and other crop seed become really difficult when the seed is processed manually and the purity reduces drastically. Bishaw (2004) also found a variation in seed purity in different districts of Ethiopia. Later Bishaw et al. (2012) reported the difference in seed quality between farmer saved seed and certified seed is mainly due to the presence of higher impurities. Also, this result is in accord with Khazaei et al. (2016) &Kshetri (2010), where they also found other crop seed and weed seed contamination minimum in certified seeds and high in farmers' seed.

Thousand weight of seed depends on various genotypic and environmental factors, from planting to harvesting. The heterogeneous samples might have caused significant variation in thousand seed weight of samples collected from different sources. The lower thousand seed weight of farmers' seed in comparison with certified or formal seed might be due to lack of seed replacement and poor crop management techniques. Besides, the farmers may be unknown about the physiological maturity of wheat, which led the early crop harvesting to produce small-sized grains. The reason behind the higher thousand-grain weight of seeds from farmers of Chitwan and Bardiya, while comparing with seeds from farmers of Baglung, might be due to variation in variety. So, from this observation, it can be said that farmers of Baglung used to cultivate smaller grains in comparison with Bardiya and Chitwan. Khan et al. (2007) also reported that the thousand-grain weight of different locations varied as we found. Also, this result is in line with Khan et al. (2007) and Kshetri (2010), where they also recorded a higher thousand seed weight in certified seeds.

Vigorous seed can be produced through the well-managed cultivation practices and the use of quality seed to boost maternal plants. The use of modern storage containers (mostly metal drum) to store seed at appropriate moisture content is a common practice of official seed producers. Also, the research station pays more attention to seed life and longevity; as a result, they maintain seed vigor for an extended period. So, the seed from NWRP provided the longest radicle & plumule length and seed vigor index. Besides, the larger size of seeds from NWRP might have imparted their positive effects on seedling length and vigor index. Variation in radicle & plumule length and seed vigor index within farmers' categories might be due to differences in seed quality caused by changes in cultivation practice, harvesting, processing, and storage techniques. In the case of farmers' seed from Baglung yielded statistically superior plumule length than the remaining three sources (Table 2). Also, seed from Baglung produced greater radicle length and seed vigor index than from farmers of Bardiya and Chitwan. Tonu et al. (2017) also agree with such variation of seed quality collected from different locations. The seedling length and vigor index varies with the genotype (cultivar) and seed size. The varieties used by farmers of Baglung may have high seed vigor, but size these seeds were substantially smaller than other regions, so these seeds are suspected of producing smaller seedling size and vigor index. Moshatati and Gharineh (2012) also described the positive effect of seed size on seed vigor and its determinants. Therefore, the Baglung district has a very high possibility of being a more favorable environment for wheat seed production and storage. Seeds from Seed Company produced the lowest seedling length and vigor index, these seeds were expected to perform better than actual. As these seeds have large seed size, there should be high rate of deterioration during harvesting and storage period, i.e., after harvesting. Very close reason is a higher rate of deterioration during storage because of the high moisture content of seed (Table 3).

Germination is the most critical aspect of seed quality and is an excellent indicator of viability. The certified category NWRP was at the top, and another certified category, seed company, was at the bottom in germination percent and normal seedling count (Table 1). The formal seeds from the seed company had the lowest germination percentage and a higher number of abnormal seedling (Table 1). Khazaei et al. (2016) and Bishaw et al. (2012) also found lower germination percent in certified seed and higher in farmers' seed. As in seed vigor, one or multiple factors like preharvest, harvest, and post-harvest factors might have led to this result. Farmers' seed provided intermediate germination percent and normal seedling count between two formal categories. Both the farmers' seed and certified seed (seed company) from the Chitwan district produced the lowest germination percent and provided the lowest vigor indices. Therefore, environmental issues during crop growth or ripening period in that area may be the reason behind the inferior status of seed. Also, from the result, it has been revealed that the Chitwan district had the most prolonged period of hot and humid weather conditions during storage time as compared with other regions (Figure 1). Also, we found high moisture content in seeds from the seed company (Table 3). Likely, Ali, Rahman, and Ahammad (2014) reported a total loss of viability of seed stored at 12% seed moisture while seed stored at 8% gave the highest germination percent in soybean after 180 days. Also, the seed viability is affected by crop growth, harvesting, and storage factors, as in the seed size and vigor indices. One or more reasons like adverse climate during crop growth, poor storage environment, hot and humid ecology, and high moisture content might be the reasons behind the poor performance of formal seed from the seed company. Yet, they have to focus more on proper storage conditions to ensure long seed life. The presence of more mechanical injury and latent injury in seeds due to various factors (moisture content at harvesting time and method of harvesting) might be reasons behind having a higher number of abnormal seedlings in farmers' seeds and seeds of the seed company.

Farmers' seeds are prone to mechanical injury because of unscientific harvesting and processing method; while considering seeds of the seed company, higher moisture content might have caused more damage to seed and produced a higher number of abnormal seedling (Andrews, 2016). High moisture content also leads to weak and unhealthy seedling production due to a high rate of deterioration. Bishaw et al. (2012) also found a significant difference in germination percentage of farmers' seed affected by location. Tonu et al. (2017) explained that germination and the portion of normal seedling depend upon seed size and health of seed. In this research, the highest germination percentage and count of the normal seedling from NARC seed can be elucidated by proper health conditions (Table 3) and an upper thousand seed weight (Table 2).

Amongst farm-saved seeds, seeds from Baglung had better germination and seed vigor index. Storage condition also determines the radicle length, plumule length, germination, and abnormality of seedlings (Nabila, Amin, Islam, Haque, & Achakzai, 2016). Elsayed, Mohamad, and Elsawy (2018) also found significant variation in seed quality parameters (protein content, germination, seedling length, seed vigor) due to the difference in the location of seed storage. High rainfall during crop growth, the mild temperature during the ripening phase, and the short hot & humid environment during the storage period were favoring the quality maintenance of wheat seed in Baglung. Thus, the ecology of Baglung might be more favorable for crop growth and the storage of wheat to maintain good physiological quality. Chitwan had a long hot and humid environment during storage time (Figure 1), lower rainfall during crop growth (Figure 1), and seeds from Chitwan are inferior in quality in comparison with others. Also, high humidity or high rainfall combined with high temperatures during the harvesting period in Chitwan was detrimental to seed quality. Bardiya had relatively low rainfall during the ripening phase, and also, the hot and humid period during ambient storage was shorter. The environment of Bardiya was not as favorable as Baglung had during ripening and ambient storage of seed. So, more studies should be done to find out certain factors behind the poor performance of seed and to improve seed quality.

The highest moisture percent was found in formal seed from the seed company (15.29 %) and least moisture percent found in legal seed from NWRP, NARC (Table 3). All the farmers' categories had a more or less similar average of moisture content. Seed absorbs moisture from the air at ambient conditions because of its' hygroscopic nature. The storage environment of the seed company might not be proper, or proper drying is absent. So that seed moisture became high under poor storage conditions in the long humid environment of Chitwan (Figure 1).

Farmers should have done proper drying and ensured appropriate storage condition to maintain moisture so their seeds were in acceptable range of moisture content (Table 3) but not safe enough to store for longer time because lower seed moisture increases the seed life and seed desiccation can be done as low as 7.6 % for bread wheat stored under ambient temperature to decrease rate of deterioration (JianFang, RongYin, LingZhi, &YiYing, 1998).

No of seeds infected by *Bipolarisspp* was found lowest in the formal seed from NWRP, NARC and farmers' seed from Baglung followed by farmers' seed from Chitwan and Bardiya; while comparing all seeds produced in Terai, the certified seed was infected significantly less in number as compared with farmers' seed (Table 3).

Less contamination of NWRP, NARC seeds to the inoculums of pathogen might be due to maintenance of seed hygiene during pre-harvest, storage, and processing. In farmers' categories, seeds from districts of Terai, i.e., Chitwan and Bardiya, are infected significantly higher than seed from the district of Hill, i.e., Baglung (Table 3). While the lower count of *Bipolarisspp* in Baglung district might be because of environmental factors (Figure 1) that varied due to altitude and geographical conditions, on the other hand, this region may contain fewer inoculums of the pathogen in comparison with Terai regions. Acharya, Dutta, and Pradhan (2011) also found *Bipolarissorokiniaya* as a severe seed-borne disease of wheat in warm and humid areas (Figure 1). Sultana and Rashid (2012) found variation in seed infection by *Bipolarissorokiniaya* amongst different samples of the same variety. So, it can be expected that the difference in *Bipolaris* infection between Terai and Hill may be due to environmental or other factors rather than genotype. The count of seeds infected with *Alternaria spp* is found very high in farmers' seed from Baglung, while the remaining three sources were affected statistically lower than farmers' seed from Baglung but similar to each other in seed infection by *Alternaria spp* (Table 3). This result is in line with Casa et al. (2011) they also found maximum infection of *Alternaria spp* in a cold and humid environment and low infection of *Alternaria spp* in warmer regions. In warmer areas, there may be a low density of inoculum. All the certified and farmers' sources of Terai have a similar count of seed infection by *Alternaria spp*. This variation may be due to the same climatic factors of this area for all these three locations. Besides climatic factors, various factors are causing natural spread and amplification of fungal diseases, such as the shared threshing floor, threshing tools, and processing tools that help to the quick spread of fungal pathogens & contaminants and amplify within a farmers' group.

CONCLUSION

The quality seed and improved varieties are important determinants for improving the crop yield.

From this research, it can be asserted that buying certified seeds does not ensure good quality, but the use of these seeds helps to avoid the risk of complete crop failure, which may occur due to own preserved seeds. So, farmers should check the quality of their own preserved seed before sowing.

If the quality status is acceptable, sowing own seed will be a good decision, but to avoid the significant loss or total crop failure, one should always go with formal seed.

Besides this, a cooler environment (Baglung district) was found better to grow and store wheat seeds under ambient conditions. Therefore, the ecology of Baglung has a higher potentiality of seed production and storage to maintain good physiological quality.

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