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Phenological Traits of Common Bean (*Phaseolus vulgaris* L., Fabaceae) Landraces

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Abstract: The study was undertaken to identify the variation of phenological traits among landraces of common bean at field conditions of rift valley of Ethiopia. Twenty four common bean landraces from different geographical areas and agroecological zones were grown in three replications. Five phenological traits were collected using IBPGR protocol. The results of the study revealed that the average fresh pod and seed maturity time of zale wehy were significantly higher ($p<0.05$) than other landraces. Date of flowering was positively correlated ($p<0.05$) with fresh pod maturity ($r = 0.42$) and dry seed maturity time ($r = 0.5$). The highest diversity (3.17) was found in days to 50% flowering, fresh pod maturity time and dry seed maturity time among landraces while the lowest diversity was found in flowering length. This indicates that there is big variation among landraces in terms of days to 50% flowering, fresh pod maturity time and dry seed maturity time; while flowering length is almost similar for all landraces. Abbajolle, dima tikka, gardoy bushay and dobole took significantly shorter times ($p<0.05$) to seed maturity. Early flowering and maturing of these landraces may give them comparative advantages to escape terminal drought that frequently occur in semi-arid areas. Therefore, crop breeders could give emphasis to these landraces to monitor and use for future production and for other purposes.

Key words: Maturity, common bean, landraces, pod, seed, traits

INTRODUCTION

Landraces are dynamic populations of cultivated plants with historical origin, distinct identity and lack formal crop improvement as well as often being genetically diverse, locally adapted and associated with traditional farming systems (Casanas *et al*., 2017; Bertoldo *et al*., 2014; Villa *et al*., 2005). They have particular characteristics (early or late maturing), a reputation for adaptation to local climatic conditions and cultural practices and resistance or tolerance to diseases, pests and various a biotic stresses (Newton *et al*., 2010; Harlan, 1992). Major advantages of landraces are adaptation to their specific agro-systems and low input requirements and factors also operate in traditional agricultural practices. It provides high yield stability and intermediate average yields under a low input agricultural system (Zemen, 1998). The genetic diversity of landraces is very important for global biodiversity conservation for future world production (Wood and Lenne, 1997).

Common bean (*Phaseolus vulgaris* L.) is the most widely grown and consumed grain legume in the world and plays an especially significant role in human diet (Khoury *et al*., 2014). Common bean is very important for food security in Latin America and East and Southern Africa. It is rich in protein and essential vitamins and minerals (Beebe, 2012). For the low-income segment of the population, common bean plays a strategic role in alleviating the rampant problems of malnutrition (Svetleva *et al*., 2006). It is cultivated in a wide range of production systems, representing different climates, soils, cultivars and levels of technology. Growth and development of crops are strongly dependent on temperature (Kar and Uzun, 2000) and soil nutrients (Araujo *et al*., 2000).

Ethiopia is a country in which the legume family holds the highest number of species (about 10% of the flora) containing many leguminous crop species known for rich inter and intraspecific diversity (Bareke *et al*., 2018). In Ethiopia, common bean is produced in almost all the regional states but with varying amount of

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production. The 75% of the total national production of common bean comes from Oromia and the Southern Nations, Nationalities and Peoples Region (SNNPR) and 25% from Afar, Amhara, Tigray, Somali, Gambella and Benishangul-Gumuz Regions (Katungi *et al.*, 2009; CSA, 2011).

Common bean contains high protein content especially in lysine which is relatively deficient in maize, cassava, rice and other cereals, making it a good complement to these staples in the diet. It promotes heart health because it is rich source of potassium, dietary fiber including cholesterol-binding soluble fiber, contain no sodium and cholesterol, fat free food, heart-healthy vegetation protein, excellent source of folic acid, consumption helps with weight management, people with diabetes who consume cooked, common bean had a lower risk of heart disease and pair well with other heart health promoting foods like fish and extra virgin olive oil (Messina, 2014).

In Southern and Eastern Ethiopia common bean is grown between 1500-2500 m a.s.l (Bareke *et al.*, 2018). Thus, determining the maturity period of common bean landraces is an important preliminary step to select the best that can survive climate changes for further use and suggest strategies in maintaining and valuing diversity (Jarvis *et al.*, 1999). This is used to estimate the existing diversity and suggest appropriate plans for the management and improvement of genetic resources in the future (Schut *et al.*, 1997). Improved high yielding short duration varieties along with proper management practices are very important to improve the resilience of farming in the drought prone areas. Changes in climate also have a variety of management implications that is early sowing and of cultivars that can escape drought through early flowering and early maturity and it is better option for risk reduction.

Ethiopia has a considerable amount of common bean genetic diversity which needs renewed conservation efforts for the region (Bareke *et al.*, 2018; Asfaw *et al.*, 2009). For conservation and use, identification of maturity time of common bean landraces is very important. Therefore, the main purpose of this study was to identify the variation of phenological traits among the common bean landraces from germplasm collection.

MATERIALS AND METHODS

The study was conducted in Melkassa Agricultural Research Center, Adama District, Ethiopia (Fig. 1).

Plant materials: The materials used in this study were 24 common bean (*Phaseolus vulgaris L.*) landraces (Table 1). The landraces were collected from different geographic origin of Oromia and Southern Nations, Nationalities and Peoples (SNNP) regions of Ethiopia (Bareke *et al.*, 2018). Sowing took place at the experimental field of the Melkassa Agricultural Research Center using irrigation. The experiment was arranged in a randomized complete block design with three replications for one season, on an experimental plot of 1.2 m^2 with 20 plants were grown per plot. To keep proper spacing and avoid competition for nutrients, space

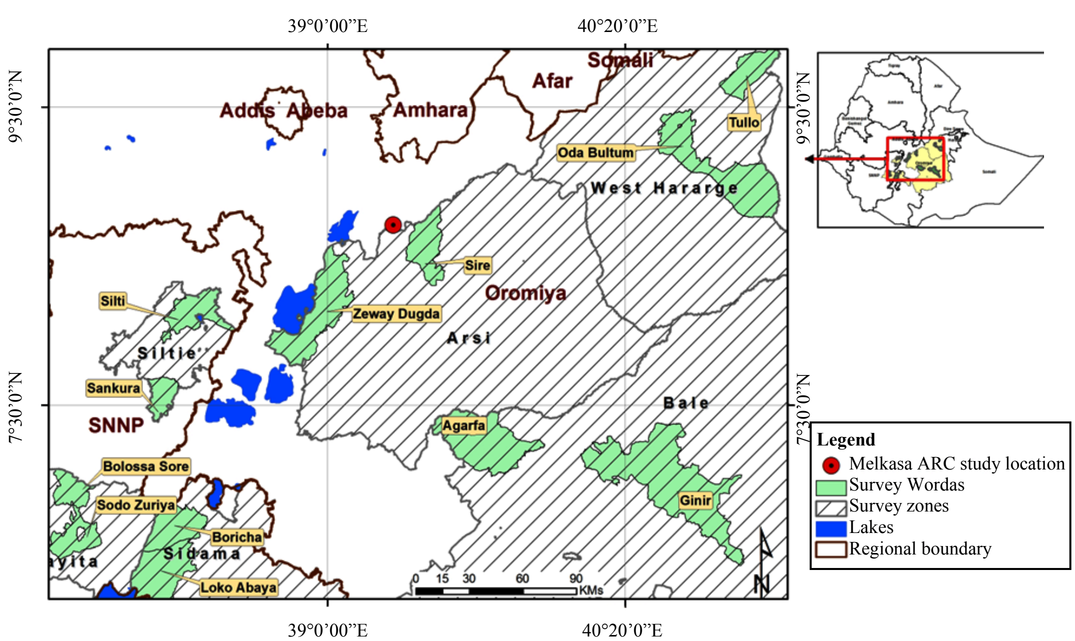

Fig. 1: Map of Ethiopia showing the sites of common bean seed collection and the experimental site

Table 1: List of common bean landraces included, along with collection and accession numbers, coordinates and region of collection sites

Accession No.	Latitude (N) (dd mm ss)	Longitude (E) (dd mm ss)	Altitude (m a.s.l)	Region	Landrace name
TBK109	08°19′02.4″	039°28′48.3″	1745	Oromia	Dima Tikka
TBK117	08°03′19.3″	038°57′39.4″	1660	Oromia	Abbajolle
TBK128	08°06′05.4″	038°58′46.8″	1673	Oromia	Dalacha Dima
TBK130	08°02′51.6″	039°00′35.9″	1682	Oromia	Bora
TBK058	07°12′35.6″	040°33′25.1″	2143	Oromia	Bar Bolokke
TBK062	07°09′53.3″	040°38′53.7″	1995	Oromia	Mishigani
TBK138	07°19′43.1″	039°51′36.3″	2401	Oromia	Zale Wehy
TBK141	07°19′43.1″	039°51′36.3″	2401	Oromia	Dobole
TBK010	08°52′22.6″	040°41′02.0″	1809	Oromia	Bora Chulukkisa
TBK018	08°53′35.3″	040°43′20.1″	1760	Oromia	Dima
TBK038	09°12′52.5″	041°06′12.7″	2180	Oromia	Adi Battee
TBK040	09°10′43.2″	041°03′22.2″	2180	Oromia	Kalibushay
TBK043	06°57′37.3″	038°20′08.9″	1856	SNNP	Yumbube
TBK152	06°41′54.4″	038°15′56.1″	1686	SNNP	Logoma Wajjo
TBK051	06°57′37.2″	038°20′08.8″	1860	SNNP	Adi Tikko
TBK048	06°57′37.2″	038°20′08.8″	1860	SNNP	Dume
TBK080	07°59′59.7″	038°18′42.4″	2190	SNNP	Zoolokoma
TBK090	08°03′56.1″	038°21′47.5″	2173	SNNP	Arusicho
TBK091	08°03′56.1″	038°21′47.5″	2173	SNNP	Logoma Dume
TBK093	08°03′56.1″	038°21′47.5″	2173	SNNP	Zoolokomakareta
TBK070	06°46′10.8″	037°45′04.6″	1872	SNNP	Dima Burre
TBK073	06°41′56.4″	037°45′44.1″	1995	SNNP	Gardoy Bushay
TBK067	07°06′25.7″	037°43′04.1″	1719	SNNP	Walensu
TBK068	06°46′11.8″	037°45′03.3″	1859	SNNP	Gumaray

Bareke *et al*. (2016)

required is 10 cm among plants and 60 cm between rows (IBPGR, 1982). Space required for water movement was 1m and space required between replications was 1.5 m. Fertilizer rates used were the homogenized mix of 120 kg DAP and 60 kg urea per hectare.

Five descriptors of common bean were evaluated for each landrace following the recommended procedure (IBPGR, 1982). Data on Germination Date/emergence (GD) (number of days from sowing until 50% of the seedlings have emerged); Days to Flowering (DF) (number of days from sowing until 50% of the plants has at least, one opened flower); Flowering Period (FP) (number of days from the beginning of flowering until 100% plants had flower abscission); Fresh Pod Maturity (FPM) (numbers of days from sowing until 50% of the plants have at least one pod with the optimal stage for fresh consumption) and dry seed maturity (number of days from sowing until 90% of the plants have reached the physiological maturity) were taken following the standard protocol (IBPGR, 1982).

Data analysis: One-way ANOVA was used to analysis the significant differences among landraces on the basis of their phenological traits.

Shannon-Wiener Index (H) was used to estimate phenological variation among landraces (Shannon and Weaver, 1949), according to the following equation:

$$\text{Shannon index } (H') = -\sum_{i=1}^{s} Pi * \ln Pi$$

Where:

H' : Shannon-Wiener diversity index

s : The number of landraces

P_i : The proportion of individuals measurement of the i^{th} phenological traits of landraces

ln : The natural logarithm

Σ : Sum from landraces 1 to landraces S

Evenness (E) was also calculated separately as a measure of the ratio of the observed diversity to the maximum diversity. It is defined by the function $E = H'/\ln s$ where H′ is Shannon index and s refers to the number of landraces recorded.

RESULTS AND DISCUSSION

The mean germination days of zoolokoma and zoolokoma kareta were significantly higher ($p<0.05$) than other landraces. These two landraces need more time to germinate whereas walensu was significantly lower ($p<0.05$) and it stays in the soil for a few days to germinate as compared to the other landraces (Table 2). The same table shows that the days to flowering of common bean landraces have no significant differences ($p<0.05$) amongst them.

The flowering length of dima tikka from the beginning of flowering until 100% plants had flower abscission was significantly higher ($p<0.05$) than the other landraces. Abbajolle and adi batte had significantly ($p<0.05$) shorter flowering period than other landraces. The mean flowering periods for all landraces ranged between 4.7 -10.7 days (Table 2).

The mean fresh pod maturity time of zale wehy was significantly different ($p<0.05$) from other landraces with the highest mean days followed by gumaray whereas abbajolle took the shortest time to reach fresh pod maturity (Table 3). Similarly, the mean dry seed maturity

Table 2: Mean 50% Germination Date (GD), Days to 50% Flowering (DF) and Flowering Period (FP) ±Standard Deviation (SD) of common bean landraces

Landraces	GD±SD	DF±SD	FP±SD
Abbajolle	14.3±3.0 abcd	56±1.7 a	4.7±0.6 c
Adi battee	12.7±3.0 abcd	57±2.6 a	5±1 bc
Adi tikko	11.3±1.2 bcd	55±0.6 a	8.7±1.5 abc
Arusicho	13±2.6 abcd	57±4.2 a	5.3±2.3 abc
Bar bolokke	12.3±0.6 abcd	54±2 a	6.3±2 abc
Bora	15 ± 2.6abc	57±3.6 a	7.3±2.8 abc
Bora chulukkisa	14.7±2.5 abc	55±2.6 a	10.3±4 ab
Dalacha dima	12.3±1.5 abcd	55±1 a	7.7±2.5 abc
Dima	13.3 ± 3.2abcd	56±3.2 a	7.7±4.6 abc
Dima burre	12.7±1.2 abcd	55±1.5 a	8.3±3.5 abc
Dima tikka	14.7±3.5 abc	55±3 a	10.7±3.5 a
Dobole	16 ± 3.6ab	57±2.6 a	6.7±0.6 abc
Dume	13.3 ± 1.5abcd	56±1 a	8.3±1.2 abc
Gardoy bushay	12±2 abcd	55±2.5 a	7.0±1 abc
Gumaray	11±1.7 cd	56±2.6 a	5.7±2.8 abc
Kalibushay	14±2.6 abcd	56±1 a	6.7±2.3 abc
Logoma dume	14.3±2.5 abcd	57±3 a	7±1 abc
Logoma wajjo	12±2.6 abcd	56± 0.1 a	6.0±0.1 abc
Mishigani	11.7±2.0 abcd	56±2 a	6.7±0.6 abc
Walensu	9.7 ± 1.5d	55±2.5 a	6.3±1.2 abc
Yumbube	13.7±2.8 abcd	56±1.5 a	5.7±0.6 abc
Zale wehy	15.7±2 abc	58±1.5 a	7.7±6.3 abc
Zoolokoma	16.5±2.1 a	58±2.8 a	8.0±1.4 abc
Zoolokoma kareta	16.3±2.8 a	55±2.3a	9.0±5.5 abc

Different letters show significant differences

Table 3: Mean Fresh Pod Maturity Time (FPMT) and 90% Dry Seed Maturity Time (DSMT) ±Standard Deviation (SD) of common bean landraces

Landraces	FPMT±SD	DSMT±SD
Abbajolle	74±1 k	84.3±1.5 j
Adi battee	81.3±1.5 efghi	92.3±2.5 de
Adi tikko	80±3 fghij	88.3±1.5 fghi
Arusicho	82.7±3 def	92±2 def
Bar bolokke	82.7±0.6 def	94.3±2.3 cd
Bora	86.3±1.5 bc	98±2 c
Bora chulukkisa	77.3±1.5 j	89.3±1.5 efgh
Dalacha dima	81.7±1.5 efgh	88±3 ghij
Dima	82±1 efg	90.7±1.2 defg
Dima burre	80.7±0.6 efghij	88.3±1.5 fghi
Dima tikka	79±1 hgi	85.3±4.2 ij
Dobole	77.3±3.5 j	86±1.7 hij
Dume	78±1 ij	87.7±2 ghij
Gardoy bushay	77.7±2 j	84.3±0.6 j
Gumaray	88.3±1.5 b	104±1 b
Kalibushay	83.7±1.2 cde	92.7±1.5 de
Logoma dume	80.7±2 efghij	94.3±2 cd
Logoma wajjo	82.7±0.6 def	94.3±2.5 cd
Mishigani	85.3±1.5 bcd	97.7±0.6 c
Walensu	78.3±2 hij	88±2.6 ghij
Yumbube	85.3±1.5 bcd	93.3±1.5 c
Zale wehy	93.3±1.5 a	112±2.6 a
Zoolokoma	80.5±0.7 efghij	85.5±0.7 hij
Zoolokoma kareta	80.7±1.2 efghij	87±1 ghij

Different letters show significant differences

time of zale wehy was significantly higher ($p<0.05$) than the other landraces. It took the longest time to mature until 90% of the plants have reached the physiological maturity followed by gumaray while abbajolle and gardoy bushay were significantly ($p<0.05$) lower than other landraces. Dry seed maturity times of these two landraces were the shortest of all landraces (Table 3).

Table 4: Correlations among all examined variables in common bean landraces at adama, Ethiopia

Pearson correlation coefficients, N = 24; Prob.>|r| under H0: Rho = 0

Traits	GD	DF	FP	FPMT	DSMT
GD	1	0.34203	0.40584*	-0.03264	-0.05997
DF	0.34203	1	-0.33166	0.41558*	0.49785*
FP	0.40584*	-0.33166	1	-0.17415	-0.22956
FPMT	-0.03264	0.41558*	-0.17415	1	0.9188****
DSMT	-0.05997	0.49785*	-0.22956	0.9188****	1

*Significant at p<0.05, **Significant at p<0.01, ***Significant at <0.001

Table 5: Shannon diversity index (H'), maximum diversity (H_{max}) and Evenness (E) for traits in 24 common bean landraces evaluated during 2016 at the Melkassa Agricultural Research Center, Adama, Ethiopia

Traits (Days)	Shannon diversity index (H′)	H_{max}	Evenness (E)
Germination date	2.40	2.79	0.86
Days to 50% flowering	3.17	4.07	0.78
Flowering period/length)	1.50	2.37	0.63
Fresh pod maturity time	3.17	4.54	0.70
Days to dry seed maturity time	3.17	4.64	0.68

Based on five phenological traits those 24 landraces were classified into 5 major categories (Figure 2). Accordingly, group I: include 1. Abbajolle, 10. Dima tikka, 12. Dobole, 14. Gardoy bushay and 24. Zoolokoma; group II: 7. Bora chulukkisa, 8. Dalacha dima, 9. Dima burre, 13. Dume, 20. Walensu and 23. Zoolokoma kareta; group III: 2. Adi battee, 3. Adi tikko, 4. Arusicho, 5. Bar boloke, 11. Dima, 16. Kalibushay, 17. Logoma wajjo, 18. Logoma DUME and 21. Yumbube; group IV: 22. Zale wehy; group V: 6. Bora, 15. Gumaray and 19. Mishigani.

As shown in Table 4, date of flowering was positively correlated ($p<0.05$) with fresh pod maturity ($r = 0.42$) and dry seed maturity time ($r = 0.5$). Germination date has direct relationship ($r = 0.4$) with flowering period at $p<0.05$. Fresh pod maturity time was positively correlated ($p<0.001$) with dry seed maturity time ($r = 0.92$). It was also positively correlated ($p<0.05$) with date of flowering.

The highest diversity (3.17) was found in days to 50% flowering, fresh pod maturity time (day) and dry seed maturity time among landraces while the lowest diversity was found in flowering length (Table 5). This indicates that there is big variation among landraces in terms of days to 50% flowering, fresh pod maturity time (day) and dry seed maturity time. On the other hand, germination date is almost similar among the landraces.

Determining of maturity time of local variety is very important to facilitate breeding efforts. Air temperature and rainfall pattern greatly affect the growth and development of common bean plants as well as its productivity (Mouhouche *et al*., 1998). In addition to this, drought and heat stress strongly influence common bean development (Kazai *et al*., 2019). Development of drought adapted common bean varieties is an important strategy to minimize crop failure and increase food

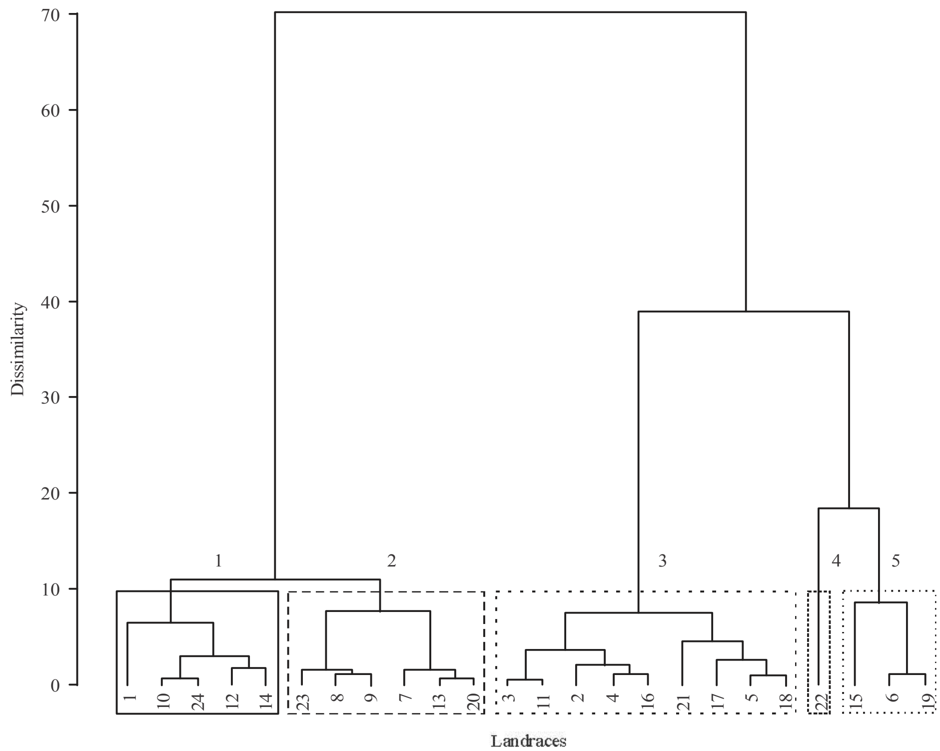

Fig. 2: Agglomerative hierarchical classification of landraces based on phenological traits; Note: 1. Abbajolle, 2. Bdi battee, 3. Adi tikko, 4. Arusicho, 5. Bar boloke, 6. Bora, 7. Bora chulukkisa, 8. Dalacha dima, 9. Dima burre, 10. Dima tikka, 11. Dima, 12. Dobole, 13. Dume, 14. Gardoy bushay, 15. Gumaray, 16. Kalibushay, 17. Logoma wajjo, 18. Logoma dume, 19. Mishigani, 20. Walensu, 21. Yumbube, 22. Zale wehy, 23. Zoolokoma kareta, 24. Zoolokoma

security in the face of climate change. Identification of key plant traits and mechanisms that contribute to improved drought adaptation can increase the efficiency of breeding programs through the selection of superior genotypes (Kargiotidou *et al.*, 2019).

The mean germination days for all landraces ranged between 9.7-16.5 days until 50% of the seedlings have emerged from the soil in the field. However, it was explained (Wallace *et al.*, 1991) that in the field, common bean landraces have completed initial germination days within 7-8 days after planting. According to sources (McCormack, 2004), if soil temperatures are below 18°C, days for seedling emergence of common bean may take 2 weeks or more. Common bean requires 18-25°C for its proper growth and development (Labuda and Brodaczewska, 2007). In field cultivation, the sowing should be made when the risk of frost is low. However, a study conducted by Suzuki *et al.* (2001) revealed that common bean plants are characterized by susceptibility to high temperatures during their generative growth. The maximum temperature during flowering should not exceed 30°C. High temperatures during the flowering stage lead to abscission of flowers and a low pod set, resulting in yield loss.

The mean days to 50% flowering for all landraces ranged between 54-58 days. Days to flowering also vary among common bean landraces which generally ranges from 35-75 days among common bean landraces in Mexico (Stoilova *et al.*, 2013). On the other hand, the variation in days to flowering ranged from 26-51 days among landraces from Uganda (Okii *et al.*, 2014). The days to flowering and the length of the flowering period of common bean varied depending on the types of landraces and environmental conditions (Wallace *et al.*, 1991).

The time taken to fresh pod maturity of these landraces was found between 2-3 months. The study conducted by Balkaya and Ergun (2007) on common bean genotypes in Turkey also indicted that the time from seed sowing to harvest varied between 71 and 143 days for fresh pod maturity time. Another study (Ibarra-Perez *et al.*, 1999) revealed that poorer pod setting on common bean may occur in the absence of pollinating insects which was proven for some dwarf cultivars. Flower and pod falling is a common phenomenon which may result from insufficient pollination of the flowers. At higher soil humidity and with shortened daylight hours, plants produce many flowers but only

7-12% of them set pods (Helena and Anna, 2007). With lower soil moisture content and longer daylight hours, plants form a lower number of flowers but 17-24% of them produce pods and therefore, the yield is higher (Prusinski and Borowska, 2002)

The time taken to dry seed maturity time of all landraces was found between 3-4 months. Seed has to undergo a period of maturation drying before harvesting and threshing are possible without causing physical damage to the seed. Maximum dry seed weight is attained at physiological maturity and it is used to improve viability and vigour of seed (Krony and Egli, 1997). The seed maturity time of common bean landraces varied widely from 50 to more than 250 days (Sandoval-Avila *et al*., 1994). It depends on the variety, photoperiod response and temperature conditions. Day temperatures below 20°C will delay maturity and cause empty mature pods to develop.

Abbajolle, dima tikka, gardoy bushay and dobole took significantly shorter times for dry seed maturity compared to other landraces. Early flowering and maturing of these landraces may help them to escape terminal drought frequently occurring in the semi-arid areas.

Many researchers (Beebe *et al*., 2011); Ramirez-Villegas *et al*., 2013) have suggested that extreme heat and drought will cause widespread losses in yields and suitability of common beans. Therefore such landraces are more economical as they take less time to grow and it is the most important and feasible climate change adaptation strategy for crop production and productivity.

CONCLUSION

Phenological variation observed among local varieties or landraces showed that there is enough scope for selection of suitable landraces for various production systems. The variability observed in 50% germination date, days to 50% flowering, flowering period or length, fresh pod maturity time and days to dry seed maturity time traits could be utilized in variety improvement programs. Abbajolle, dima tikka, gardoy bushay and dobole are significantly fast maturing varieties compared to the other landraces. Therefore, crop breeders could give priority and emphasis to these landraces to monitor and use for the future production and for other purposes.

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