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# EVALUATING SCIENTIFIC NAMES, DISTRIBUTION, AND RECORD TYPES OF ETHIOPIAN PEA BASED ON GLOBAL DATASETS USING CLASSIFICATION REGRESSION TREE ANALYSES

**Berhane Gebreslassie GEBREEGZIABHER[1], Berhanu Abraha TSEGAY[2]**

[1]Woldia University, Faculty of Natural and Computational Sciences, Department of Biology, P.O. box 400, Woldia, Ethiopia
[2]Bahir Dar University, College of Science, Department of Biology, P.O. box 76, Bahir Dar, Ethiopia

Corresponding author email: birie2006@gmail.com

***Abstract***

*Biodiversity conservation is dependent on correct taxonomic cataloguing and searchable databases structuring. Ethiopian pea has few seed accessions and has been excluded from many Pisum studies; its true taxonomic status is still dubious. This necessitates evaluating the crop's scientific names, distribution and record types on the global datasets. A total of 367 Ethiopian pea collections described with four scientific names, from 19 global datasets were used. The population included unknown record types, living and preserved specimens, and cultivated landraces. Classification and Regression Tree analysis was used as an evaluation tool. Names of the taxon were analysed as 271 Pisum abyssinicum A. Braun, 88 Pisum sativum subsp. abyssinicum (A. Braun) Govorov, 7 Pisum sativum var. abyssinicum A. Braun, and 1 Pisum abyssinicum A. Braun var. vavilovianum Gov. Most of them (305) were unknown, 37 preserved specimens, 19 living specimens, and 6 cultivated record types. Of these, 184 unknown, 22 preserved specimens, 12 living specimens, and 6 cultivated types are collected from Ethiopia. The preserved and living specimens were subspecies types. There is an urgent need to conserve the crop via sufficient documentation at current situation.*

***Key words****: datasets, inconsistency, living specimen, preserved specimen.*

## INTRODUCTION

Ethiopian pea is a crop of practical interest for crop genetic diversity enhancement (Kosterin, 2017; Tsegay and Gebreegziabher, 2019). Ethiopian pea contains genes likely to be involved in the physiological and biochemical processes useful for developing more productive, nutritious and resilient varieties. These includes the genes for the early stages of nodule formation (Weeden, 2007; Abbo et al., 2014), delightful taste, early flowering, and early maturity (Weeden, 2007; Yemane and Skjelvåg 2003; Weller et al., 2012; Smýkal et al., 2015; MoANR, 2016; Kosterin, 2017; Rubenach et al., 2017; Gebreegziabher and Tsegay, 2018). Ethiopian pea maturity is determined by the stock of small quantitative genes (Yarnell, 1962) that help to escape terminal drought. It owns genes resistant to viruses such as eIF4E gene particularly; $eIF4E^B$ allele in its germplasm (Konečná et al., 2014) and pea bacterial blight resistance genes (Kumar and Hirochika, 2001; Elvira-Recuenco et al., 2003; Hollaway et al., 2007; Kole, 2011; Martín-sanz et al., 2012). Ethiopian pea has ribosomal transcribed spacing genes used to systematic analysis of closely related pea taxa (Polans and Saar, 2002). Ethiopian pea can, therefore, play a significant role in maintaining global food security and ecosystem resilience. But, Ethiopian pea is less utilized both locally and globally due to the lack of clear information in its origin, domestication process, geographical distribution, and obtainable worldwide inventories. These all may contribute to the obscure identification of the taxon. Even in Ethiopia where the crop is native, less attention is given for this crop and is cultivated rarely at small scale farming for local consumption and local market. Moreover, there is no sufficient research done on the crop which required this analysis.

The English local name, Ethiopian pea was first described by Georg Wilhelm Schimper from 1837 to 1878 in Northern Ethiopia (McEwan, 2018). The type specimen was collected in 1840 and is stored at the herbarium of National Botanic Garden of Belgium (BR, BR0000006255831). Alexander Karl Heinrich

Braun (1805-1877) termed the crop scientific name as *P. abyssinicum.* However, in Ethiopia, it was documented in 1989 in the third volume flora of Ethiopia as *Pisum sativum* var. *abyssinicum* A. Braun (Hedberg and Edwards, 1989). But, a recent study by Holden (2009) claimed that the origin of Ethiopian pea is doubtful. From the studies by Kosterin (2016) and Trnèný et al. (2018), domestication process and the identity of the wild progenitors of Ethiopian pea are reported as unknown. Still there is no full agreement on its domestication process and its domesticated nature. It is considered as wild type by some authors (Zong et al., 2009; Smýkal et al., 2011; Weeden, 2018).

Ethiopian pea is suggested as domesticated crop independently rather than a hybrid origin by several authors (Westphal, 1974; Ellis and Poyser, 1998; Ellis and Poyser, 2002; Vershinin et al., 2003; Baranger et al., 2004; Jing et al., 2010; Smýkal et al., 2011; Sindhu et al., 2014; Trnèný et al., 2018; Weeden, 2018). For many years, different authors also studied the geographical distribution, evolution and germination of Ethiopian pea (Westphal, 1974; Kole, 2011; Abbo et al., 2014; Gebreslassie and Abraha, 2016). Previous studies reported that Ethiopian pea is confined to the highlands of Ethiopia although some accessions have been attributed to Yemen (Ellis and Poyser, 2002; Holden, 2009; Trnèný et al., 2018). Recent report by Mansfeld's World Database of Agricultural and Horticultural Crops generated on 13 April 2019 indicated that Ethiopian pea may escape to other parts of the World (Tsegay and Gebreegziabher, 2019).

The narrow distributional range and less biologically conserved of Ethiopian pea could be resulted from its domestication process, because, domestication process is stated as a role player for narrow eco-geographical range of peas by many authors (Weeden and Wolko, 2001; Weeden, 2007; Doust et al., 2014; Konečná et al., 2014; Trnèný et al., 2018; Weeden, 2018). Amano and Sutherland (2013) in their study also identified geographical location or distribution as one of the barriers to the global understanding of biodiversity conservation.

Ethiopian pea has few seed accessions available and has been excluded from many *Pisum* studies, and as a result its true taxonomic status is still dubious (Maxted and Ambrose, 2001). Initially it was described as a separate species by Alexander Karl Heinrich Braun in 1841 (Trnèný et al., 2018) and adopted in the same rank by many authors (Ellis et al., 1998; Maxted and Ambrose, 2001; Vershinin et al., 2003; Kosterin and Bogdanova, 2008 and 2015; Maxted and Kell, 2009; Kosterin et al., 2010; Zaytseva et al., 2012 and 2015). But this taxonomy is not universally accepted because of the subspecies and/or varietal level ranks reported by several authors (Westphal, 1974; Hedberg and Edwards, 1989; Yemane and Skjelvåg, 2003; Edwards et al., 2007; Holden, 2009; Jing et al., 2010; Ellis, 2011; Keneni et al., 2013; Sindhu et al., 2014; Tsegay and Gebreslassie, 2014; Gebreslassie and Abraha, 2016; Gebreegziabher and Tsegay, 2018; Weeden, 2007 and 2018, Tsegay and Gebreegziabher, 2019). Kosterin (2017) has morphologically renamed Ethiopian pea as Lathyrus schaeferi Kosterin pro *Pisum abyssinicum* A. Bruan. From the current study however it has been observed that, preserved and living specimens in most datasets were subspecies types and the varietal collections are mostly cultivated types.

## MATERIALS AND METHODS

### Ethiopian pea collections and the datasets

A total of 367 Ethiopian peas collections described with four different scientific names, from different global datasets were used for this analysis (Table 1). The pea collections were collected from 19 international datasets and included unknown record types, living specimens, preserved specimens, and plant types that are at present under small scale farming cultivations (Table 1).

### Statistical analyses

Classification and Regression Tree (CART) analysis using Statistical Package for the Social Sciences (SPSS) version 25 software was used to evaluate optimal outcomes with minimum variances from predictors. The CART algorithm builds a binary regression tree by partitioning a node into two new nodes, until the variance within the nodes is minimized and the variance between the nodes is maximized

(Loh, 2011; West, 2012; Trendowicz and Jeffery, 2014; Wang et al., 2017).

Table 1. Global distribution of Ethiopian pea by country areas and datasets

| Country areas of collection | Ethiopian pea (Number) | Ethiopian pea (%) | Datasets (Number of Ethiopian pea) |
|---|---|---|---|
| Afghanistan | 61 | 16.6 | I(60),VIII(1) |
| Argentina | 1 | 0.3 | I(1) |
| Denmark | 3 | 0.8 | I(1) |
| Ethiopia | 224 | 61.0 | I(147), II(1), III(2), IV(3), V(1), VI(2), VII(14), VIII(11), IX(10), X(1), XI(12), XII (12), XV(1), XVI(6), XIX(1) |
| Germany | 1 | 0.3 | XIV(1) |
| Greece | 2 | 0.5 | I(2), II(1), |
| Italy | 2 | 0.5 | I(2) |
| Libya | 1 | 0.3 | I(1) |
| Morocco | 1 | 0.3 | VIII(1) |
| Russian Federation | 10 | 2.7 | I(7), VII(2), XIII(1) |
| Sweden | 2 | 0.5 | VIII(2) |
| United Kingdom | 27 | 4.7 | I(21), IV(1), VII(4), XI(1) |
| United States of America | 2 | 0.5 | IX(2) |
| Yemen | 7 | 1.9 | I(6),VIII(1) |
| Unknown country | 23 | 6.3 | I(2), II(2), III(1), IX(3), XI(7), XII(5), XVII(2), XVIII(1) |
| Total | 367 | 100 | 19(367) |

Note! I=A global database for distribution of crop wild relatives, II= Naturalis Biodiversity Center (NL)-Botany, III= The Vascular Plant Collection at the Botanische Staatssammlung München, IV= Natural History Museum, Vienna - Herbarium W, V= Herbarium specimens of Université de Montpellier 2, Institut de Botanique (MPU), VI= Meise Botanic Garden Herbarium (BR), VII= The System-wide Information Network for Genetic Resources (SINGER), VIII= United States National Plant Germplasm System Collection, IX= Nordic Genetic Resources, X= Centre for Genetic Resources, the Netherlands, PGR passport data, XI= EURISCOXI, The European Genetic Resources Search Catalogue, XII= SINGR Coordinator, XIII= Royal Botanic Garden Edinburgh Living Plant Collections (E), XIV= CZE National PGR Inventory, XV=Ethiopian Biodiversity Institute (EBI), XVI= Farmers landrace, XVII= Tropicos Specimen Data, XVIII= Jardin Botanique de Lyon, XIX= RB - Rio de Janeiro Botanical Garden Herbarium Collection.

Numbers of nodes were defined for each output with a parent to child nodes ratio of 5:1. The CART decision diagram for the scientific names of Ethiopian pea based on the datasets was defined at the minimum cases of 1:1 parent to child node ratio to split datasets containing only a single Ethiopian pea species. The command order used in the SPSS (Statistical Package for the Social Sciences), also known as IBM SPSS Statistics was Analyse → Classify → Tree, where IBM stands for International Business Machines Corporation. The cross validation was set to 10 and tree depth to 5. Pruning was activated to prevent unnecessary branching. Optimal splits were defined by improvement value for variables output. Overlapping occurs when a predictor is significant on more than one group within the same branch, and results in objects being assigned in more than one category (Loh, 2011; Díaz-Pérez and Bethencourt-Cejas, 2016). The minimum change in improvement value was used as the minimum decrease in impurity required in splitting a node. A terminal node in which all cases have the same value for the dependent variable is considered as a homogeneous or pure node (SPSS Classification Trees™ 13.0, 2004).

## RESULTS AND DISCUSSIONS

### Taxonomic evaluation of Ethiopian pea collections

In order to examine the overall taxonomy of Ethiopian pea collections from the global datasets, 19 global biodiversity datasets, which may be indicative of data availability across the studied countries, were used. CART analysis was used to analyse taxonomic inventory of the 367 Ethiopian pea collections outcomes with minimum variances from the 19 global datasets. The CART growth model analyses result showed that the species, subspecies, and varietal ranks are used globally for the single Ethiopian pea taxon. These were *Pisum abyssinicum* A. Braun, *Pisum sativum* subsp. *abyssinicum* (A. Braun) Govorov, *Pisum sativum* var. *abyssinicum* A. Braun, and *Pisum abyssinicum* A. Braun var. *vavilovianum* Gov. from the most to the list, respectively (Table 2). The current study analyzed that the commonly known was *P. abyssinicum* A. Braun by about 73.8% of the total collections (Table 2).

Such findings to our knowledge are the first to demonstrate that, the taxon was documented with three different taxonomic ranks and four different record types. Moreover, the current study present a first methodical global assessment of the *ex situ* and *in situ* upkeep status of Ethiopian pea collections. Ethiopian pea was described as *P. sativum* subsp. *abyssinicum* (A. Braun) Govorov with 24% of all the species (Table 2) when analysed by the crop collection countries. There were no previous reports indicating about inconsistencies of Ethiopian pea taxonomy, country areas of collection, and record types from global datasets.

Table 2. Taxonomic status proportion of Ethiopian pea collections under global datasets

| Scientific name | Taxonomic status | | |
|---|---|---|---|
| | Species | Subspecies | Variety |
| *P. abyssinicum* A. Braun | 271(73.8%) | - | - |
| *P. abyssinicum* A. Braun var.*vavilovianum* Gov | - | - | 1(0.3%) |
| *P. sativum* subsp. *abyssinicum* (A. Braun) Govorov | - | 88(24%) | - |
| *P. sativum* var. *abyssinicum* A. Braun | - | - | 7(1.9%) |

## Evaluating scientific names of the Ethiopian pea collections based on country areas of collection

Scientific names of Ethiopian pea across global datasets as evaluated by country areas of collection are presented in table 3 below. It has been estimated that the 67 collections from Afghanistan, Libya, Italy, Greece and Argentina were solely of *P. abyssinicum* A. Braun. Similarly, 7 of the Ethiopian pea collections from Yemen were 6 *P. abyssinicum* A. Braun with 1 *P. sativum* subsp. *abyssinicum* (A. Braun) Govorov. For Ethiopian collections, the Ethiopian pea was found as identifiable by the three taxonomic ranks viz. *P. abyssinicum* A. Braun 157(70.1%), *P. sativum* subsp. *abyssinicum* (A.Braun) Govorov 60(26.8%) and *P. sativum* var. *abyssinicum* A. Braun 7 (3.1%). Ethiopia collection accounts 61% of the total Ethiopian pea collections of the datasets. Furthermore, the 29 collections from United Kingdom and Russian Federation were analyzed to be *P. abyssinicum* A. Braun.

A scientific name clustering of Ethiopian pea collections using classification and regression analysis was done for 6 Ethiopian pea collections from the United States of America, Sweden, Germany and Morocco (improvement value = 0.006). It was found that they all were *P. sativum* subsp. *abyssinicum* (A. Braun) Govorov subspecies types (Table 3). After final repulsive splitting of the CART analysis with nodes (improvement value = 0.000), 23 of the Ethiopian pea collections were identified as they were from unknown areas of collection (Table 3). The 3 Ethiopian pea collections were obtained from Denmark were 2 *P. sativum* subsp. *abyssinicum* (A. Braun) Govorov and 1 *P. abyssinicum* A. Braun (Table 3).

From the reverse analyses (area of collection by scientific name), it was observed that about 224 (61%) of the crop collections are from Ethiopia (Table 3). Sixty one (16.6%) of the Ethiopian pea collections was from Afghanistan (Table 3) which signposts probability of domestication history of the crop in Afghanistan. But, evaluated results as unknown record types for the Ethiopian pea collections from Afghanistan made this suggestion weak. Moreover, from the 88 subspecies designated as *P. sativum* subsp. *abyssinicum* (A. Bruan) Govorov, 60 of them were analyzed as Ethiopian collections (Table 3) at the improvement value of 0.002 as significance test. Eleven of the Ethiopian pea subspecies were evaluated as not known from where they were collected. The rest 17 Ethiopian pea subspecies were sporadically distributed to United Kingdom (6), Denmark (2), Russian Federation (2), Sweden (2), United States of America (2) Germany (1) Morocco (1) and Yemen (1). Likewise, scientific name as an explainer variable foretells that *P. sativum* var. *abyssinicum* A. Braun with a varietal taxonomic rank was uniquely found in Ethiopia (Table 3).

Table 3. Ethiopian pea scientific names evaluated by countries areas of collection

| Scientific names | Collecting countries (Number of species) |
|---|---|
| *P. abyssinicum* A. Braun | Afghanistan (61), Argentina (1), Denmark (1), Ethiopia (157), Greece (2), Italy (2), Libya (1), Russian Federation (8), United Kingdom (21), Yemen (6), and Unknown (11) |
| *P. sativum* subsp. *abyssinicum* (A. Braun) Govorov | Denmark (2), Ethiopia (60), Germany (1), Morocco (1), Russian Federation (2), Sweden (2), United Kingdom (6), United States of America (2), Yemen (1), and Unknown (11) |
| *P. sativum* var. *abyssinicum* A. Braun | Ethiopia (7) |
| *Pisum abyssinicum* A. Braun var. *vavilovianum* Gov. | Unknown (1) |

## Evaluation of Ethiopian pea scientific names based on global record types

It was analysed that 305 of the Ethiopian pea collections were with unrevealed record types described by two scientific names (Table 4). Of these, 252 (82.6%) of them were *P. abyssinicum* A. Braun and 53 (17.4%) were *P. sativum* subsp. *abyssinicum* (A. Braun) Govorov. Six of the cultivated Ethiopian pea collections were analyzed as having the scientific name of *P. sativum* var. *abyssinicum* A. Braun (Table 4). Moreover, the CART analysis enable to distinguish the scientific

names of the 37 preserved specimens and 19 living specimens, record types (Table 4). However, there were only 17 preserved specimens, 2 living specimens with the scientific name *P. abyssinicum* A. Braun through the datasets (Table 4).

Table 4. Ethiopian pea collections scientific names as evaluated by record types

| Scientific name | Record type | | | | | |
|---|---|---|---|---|---|---|
| | Cultivated | Living specimens | Preserved specimens | Unknown | Total | % |
| *P. abyssinicum* A. Braun | - | 2 | 17 | 252 | 271 | 73.8 |
| *P. abyssinicum* A. Braun var.*vavilovianum* Gov | - | - | 1 | - | 1 | 0.3 |
| *P. sativum* subsp. *abyssinicum* (A. Braun) Govorov | - | 16 | 19 | 53 | 88 | 24 |
| *P. sativum* var. *abyssinicum* A. Braun | 6 | 1 | - | - | 1 | 1.9 |
| Total number of Ethiopian peas | 6 | 19 | 37 | 305 | 367 | 100 |

**Evaluation of Ethiopian pea collections scientific names based on global datasets**

Scientific names of Ethiopian pea collections were evaluated per datasets. Datasets namely Naturalis Biodiversity Center (NL)-Botany and Natural History Museum, Vienna - Herbarium W. were estimated as having 7 Ethiopian pea collections with 2 and 3 *P. abyssinicum* A. Braun, and 1 each *P. sativum* subsp. *abyssinicum* (A. Braun) Govorov, respectively (Table 5). Datasets: (1) A global database for distribution of crop wild relatives, (2). The Vascular Plant Collection at the Botanische Staatssammlung München, (3) Herbarium specimens of Université de Montpellier 2, Institut de Botanique (MPU), (4) Meise Botanic Garden Herbarium, (5) Royal Botanic Garden Edinburgh Living Plant Collections, (6) Tropicos Specimen Data and (7) RB-Rio de Janeiro Botanical Garden Herbarium Collection were evaluated all together containing 260 Ethiopian pea collections designated as *P. abyssinicum* A. Braun (Table 5). The EURISCO, The European Genetic Resources Search Catalogue dataset was the only dataset that contains the species (1), subspecies (17) and variety (1) taxonomic ranks of the Ethiopian pea collections globally (Table 5). Datasets: (1) The System-wide Information Network for Genetic Resources (SINGER), (2) United States National Plant Germplasm System Collection, and (3) Nordic Genetic Resources contained 19, 17, and 13 *P. sativum* subsp. *abyssinicum* (A. Braun) Govorov and 1 each *P. abyssinicum* A. Braun, respectively (Table 5). Datasets: (1) Centre for Genetic Resources, the Netherlands, PGR passport data, (2) SINGER Coordinator, (3) CZE National PGR Inventory and (4) Jardin Botanique de Lyon were evaluated as contained 20 Ethiopian pea collections that were partitioned as 1, 17, 1 and 1 *P. sativum* subsp. *abyssinicum* (A. Braun) Govorov per each dataset, respectively (Table 5).

Table 5. Scientific names as evaluated by global datasets

| Scientific names | Dataset/s (Number of collections) |
|---|---|
| 1. *P. abyssinicum* A. Braun accounts 271 (73.8%) of the total collections from the 13 (64.42%) global datasets. | 1. A global database for distribution of crop wild relatives (250) |
| | 2. Naturalis Biodiversity Center (NL)-Botany (2) |
| | 3. The Vascular Plant Collection at the Botanische Staatssammlung München (3) |
| | 4. Natural History Museum, Vienna - Herbarium W (3) |
| | 5. Herbarium specimens of Université de Montpellier 2, Institut de Botanique (MPU) (1) |
| | 6. Meise Botanic Garden Herbarium (BR) (2) |
| | 7. The System-wide Information Network for Genetic Resources (SINGER) (1) |
| | 8. United States National Plant Germplasm System Collection (1) |
| | 9. Nordic Genetic Resources (1) |
| | 10. EURISCO, The European Genetic Resources Search Catalogue (3) |
| | 11. Royal Botanic Garden Edinburgh Living Plant Collections (E) (1) |
| | 12. Tropicos Specimen Data (2) |
| | 13. RB - Rio de Janeiro Botanical Garden Herbarium Collection (1) |
| 2. *P. sativum* subsp. *abyssinicum* (A. Braun) Govorov accounts 88(24%) of the total collections from the 10 (52.63%) global datasets. | 1. Naturalis Biodiversity Center (NL)-Botany (1) |
| | 2. Natural History Museum, Vienna - Herbarium W (1) |
| | 3. The System-wide Information Network for Genetic Resources (SINGER) (19) |
| | 4. United States National Plant Germplasm System Collection (17) |
| | 5. Nordic Genetic Resources (13) |
| | 6. Centre for Genetic Resources, the Netherlands, PGR passport data (1) |
| | 7. EURISCO, The European Genetic Resources Search Catalogue (17) |
| | 8. SINGER Coordinator (17) |
| | 9. CZE National PGR Inventory (1) |
| | 10. Jardin Botanique de Lyon (1) |
| 3. *P. sativum* var. *abyssinicum* A. Braun books 7(1.9%) of the whole collections which are exclusively from Ethiopia | 1. Ethiopian Biodiversity Institute (EBI) (1) |
| | 2. Ethiopian farmers landrace (6) |
| 4. *P. abyssinicum* A. Braun var. *vavilovianum* Gov. This is the only and singly varietal type found at *ex situ* upkeep status. | 1. EURISCO, The European Genetic Resources Search Catalogue (1) |

**Ethiopian pea record types distribution evaluation among the global datasets**

Examined occurrences results per basis of record for the 367 Ethiopian pea collections based on their frequency distribution in the global datasets were analysed. Results indicated that, 305 (83.1%) of the Ethiopian pea collections were obscurely recorded, 37 (10.1%) were preserved specimens, 19 (5.2%) were living species and 6 (1.6%) are still landraces or farmers cultivars at small farming scale in Ethiopia. The unknown record types were mostly found from datasets; (1) A global database for the distribution of Crop Wild Relatives (250), (2) The System-wide Information Network for Genetic Resources (SINGER) (20), and (3) United States National Plant Germplasm System Collection (18). EURISCO, The European Genetic Resources Search Catalogue dataset is found to owing most number of preserved species (21). Nordic Genetic Resource was the dataset having more number of living specimens (14). Both preserved (3) and living (1) specimens were found from Natural History Museum, Vienna - Herbarium W dataset, and living (1) and cultivated (6) were from Ethiopian datasets.

**Ethiopian pea global country areas of occurrence based on record types**

CART based analysis was carried out to clarify how the global Ethiopian pea collections were documented per country (Figure 1). The collection sites of the 23 (6.3%) Ethiopian peas were not known (Node 0). Ethiopian collections were documented as 22 (59.5%) preserved specimen (Node 3), 12 (63.2%) living specimen (Node 4), 184 (60.3%) unknown types (Node 5), and 6 (100%) cultivated (Node 6). The Afghanistan Ethiopian pea collections were not specified what record types they are (Figure 1, Node 5). The total 37 preserved specimens representing the species, subspecies and variety taxonomic ranks (Table 5) were analyzed (improvement = 0.002) from the19 global datasets (Node 3). These were analysed as collected from Ethiopia (22), unknown (13), United Kingdom (1), and Denmark (1). Moreover, analysis was carried out for the living specimens at the improvement value 0.003. There were 19 living specimens across the global datasets collected from five country areas (Node 4) namely Ethiopia (12), unknown (3), United Kingdom (1), Germany (1), Denmark (1), and Russian Federation (1). The unknown record types were found in all the collection areas except Germany (Node 5). Most were from Ethiopia (184), Afghanistan (61), United Kingdom (25), and Russian Federation (9), respectively. The others were from Yemen (7), United States of America (2), Sweden (2), Greece (2), Italy (2), Argentina (1), Denmark (1), Libya (1) and Morocco (1). This indicated that, there were no clear protruding characterization and adoption works done yet for exactness whether the global collections were of Ethiopian peas existing and cultivated in its present range in North Ethiopia or not.

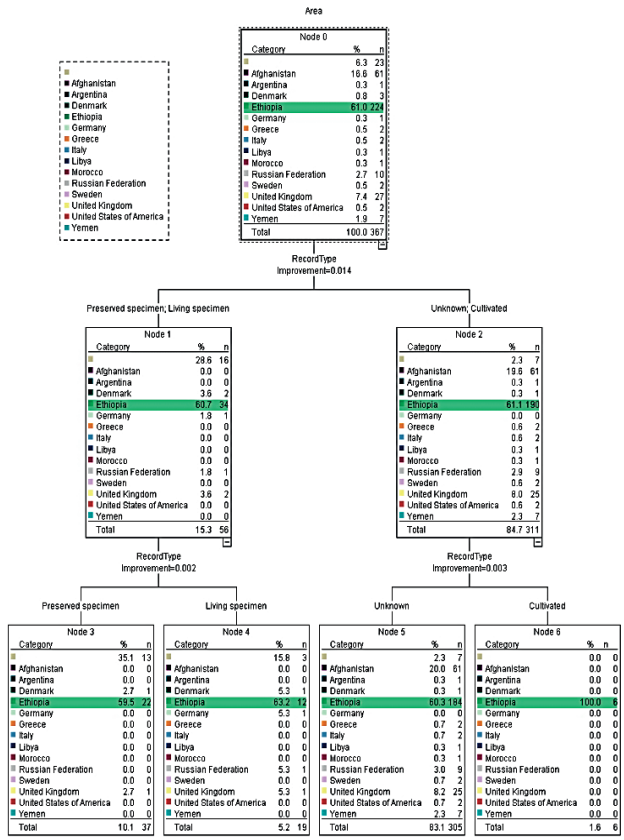


Figure 1. The CART decision diagram for global country areas of collection distribution of Ethiopian pea as evaluated by record types at the minimum cases of 5 parent nodes and 1 child node. Nodes were determined by the significance using improvement values where green ones were predicted categories

From the above results the following arguments were conferred. Though Abyssinia, the now Ethiopia is one of the eight centres of crop diversity (Turrill, 1926; Vavilov, 1935; Hawkes, 1993; Hunter et al., 2012; Delêtre et

al., 2012), habitat loss in the Ethiopian montane grasslands and woodlands eco-region is the peak with 82.5% (Stolton et al., 2008) that require clarion call for the more recently advocated in natural habitat (*in situ*) conservation priority of agrobiodiversity. Presently, the Ethiopian pea traditional crop varieties or landraces have *in situ* protection status of 8.4% (Stolton et al., 2008; Delêtre et al., 2012) which is below the 10% minimum International Union for the Conservation of Nature (IUCN) recommended level of protection (Stolton et al., 2008). Although CSA has no statistics yet on Ethiopian pea (Bishaw et al., 2018), MoANR (2016) reported that, there are two Ethiopian pea (RAYA-1 and RAYA-2) varieties released in 2015. Beyond being hotspot, among the 34 global hotspots (Myers et al., 2000; Delêtre et al., 2012), Ethiopia idyllically is the conservation priority site to contain exceptional plant endemism and exceptional threat (Myers et al., 2000; Giam et al., 2010; Delêtre et al., 2012) and more likely to feature further priority areas for crop gene pools (Maxted and Kell, 2009; Hunter et al., 2012). Hence, this evaluation study was not about Ethiopian pea taxonomy, rather it discussed about the world-wide inventories of Ethiopian pea for further *in situ* agroecological based landraces diversity protection.

Scientific names information has a special significance to link information elements to biodiversity and conservation studies (Husen et al., 2012; Hardisty and Roberts, 2013). From the current study, it was believed that the taxonomic ambiguity of the Ethiopian pea can impair its effective *ex situ* and *in situ* conservation priorities and the potential use as plant genetic improvement resource for future reference. In biodiversity conservation, there is need of taxonomic identification at species, subspecies and population level (Husen et al., 2012). This is because biodiversity conservation and obtainability of plant genetic resources are dependent on the correct taxonomic cataloguing and on the structuring of searchable databases (Baillie et al., 2008; Husen et al., 2012; Hardisty and Roberts, 2013; Ely et al., 2017; Korpelainen and Pietiläinen, 2019). Moreover taxonomic ambiguity of the crop may contribute to its limited distribution, less known of its origin (Berg, 2009; Holden, 2009) and domestication background globally confirming the reports from various authors (Hassan, 2002; Ellis, 2011; Mikić and Mihailović, 2014; Gebreegziabher and Tsegay, 2018).

In addition, the narrow in genetic basis of Ethiopian pea (Mikić and Mihailović, 2014) could be perhaps, due to the lack of eminence biodiversity data on taxonomic and varietal types; the communal occasion within *Pisum* genus (Zong et al., 2009; Hardisty and Roberts, 2013) except *P. sativum* var. *abyssinicum* A. Braun from Ethiopia and *P. abyssinicum* A. Braun var. *vavilovianum* Gov. from unknown area of collection. Abbo et al. (2014) have reported that the narrow eco-geographic distribution and unknown wild progenitor of legume crops hinder their growth performances improvement and their utilization. This showed the sporadic distribution of the crop analogous to the claims by some authors (Yemane and Skjelvåg, 2003; Mikić and Mihailović, 2014; Gebreegziabher and Tsegay, 2018).

Ethiopian peas collected from Ethiopia were evaluated to contain three of the taxonomic ranks, showing probably better collection priority of the country. Previous authors have been suggested that Ethiopia can be recommended as Ethiopian pea collection priority and hypothesized primary gene pool selection area (Maxted and Kell, 2009; Smýkal et al., 2015). Finding from Teshome et al. (2014), also explored the primary gene pool of field peas from Ethiopia as a potential source of pea weevil resistance. In addition, Zong et al. (2009), recommended that genetic potentials in the Abyssinian Centre (Ethiopia) one among the eight Vavilov' centers of diversity. Maxted and Kell (2009) in their study also suggested that gene pools from the eight Vavilov' centers of diversity should be thoroughly exploited in order to broaden the genetic bases of pea varieties. Moreover, it could be better explained that Ethiopia is the center of diversity for this top 14 priority crop wild relative species (Maxted and Kell, 2009; FAO, 2010; MoANR, 2016; Mikić, 2018).

Strengthening this idea, Ethiopia is described as domestication origin and distribution of the endemic Ethiopian pea taxa in the Ancient

Mediterranean area of origin of cultivated plants (https://www.bioversityinternational.org/fileadmin/bioversity/publications/Web_version/47/ch06.htm; Gebreslassie and Abraha, 2016; Nováková et al., 2019).

From a paleontological standpoint, Ethiopia is also stated as centers of diversity for Ethiopian pea, one of the economically most important pulse crops in the world and throughout the history (Zeven and Zhukovsky, 1975; Delêtre et al., 2012). Here too is shown that Ethiopia is better collection area of Ethiopian pea as shown from (75%) of the scientific names used for the collections. This is comparable to what has been stated by many authors (Yarnell, 1962; Abbo et al., 2003; Baranger et al., 2004; Gixhari et al., 2014). Similarly, insufficient geographical information of accessions, confusion of germplasm collections about Ethiopian pea and the between countries taxonomic variety may contribute in the crop unsatisfactory taxonomic suggestions (Mikić et al., 2013; Burstin et al., 2015; Kosterin, 2017; Bogdanova et al., 2018).

The scientific names analysed based on record types directed the authors to suggest the supposed species name of the crop as *P. abyssinicum* A. Braun was related to the inadequate investigation done on the crop's taxonomy, collection, recording, and agrobiology. Therefore, it can be discoursed that, the cultivated record type was evaluated to be *P. sativum* var. *abyssinicum* A. Braun type. This confirms the report by Ellis and Poyser (2002) who stated *P. abyssinicum* is a variety of cultivated pea with *P. sativum* in Ethiopia. Ethiopian pea collections designated with farmers landraces dataset predicted as cultivated types are growing sporadically in North Ethiopia (Westphal, 1974; Gebreegziabher and Tsegay, 2018; Tsegay and Gebreegziabher; 2019) which can be of good breeding resources supporting the report that pea breeding will rely on exploitable resources that can be found in the cultivated stated (Ellis and Poyser, 2002; Burstin et al., 2015). The present analysis result were contrary to the previous reports by some authors (Zong et al., 2009; Smýkal et al., 2011; Burstin et al., 2015) who considered *P. abyssinicum* as wild type. *P. abyssinicum* A. Braun var. *vavilovianum* Gov. and *P. sativum* var. *abyssinicum* A. Braun were the only varietal preserved and living specimens, respectively. From this analysis it can be suggested that there might be gaps with the genetic studies conducted so far for Ethiopian pea which might use the unknown record types designated with *P. abyssinicum* A. Braun. This might basket genetic diversity and conservation effort of the preserved specimens, living specimens and cultivated types of the crop from the available datasets. Similar cases were reported by some authors (Ely et al., 2017; Guzzon and Ardenghi, 2018; Sales et al., 2018) for other legume crops on use of dataset information to indicate the implications of poor taxonomy, taxonomic misnaming, and hidden diversity on conservation efforts and usage of plant genetic resources.

Limited to these datasets, Ethiopian pea was relatively represented by the *P. abyssinicum* A. Braun species rank, ratifying the description and adoption of the crop taxonomic rank by many scholars (Errico et al., 1991; Ellis et al., 1998; Vershinin et al., 2003; Baranger et al., 2004; Ellis, 2011; Zaytseva et al., 2015). On the other hand, the existence of evidences with the varietal scientific name designation both from the currently examined data and the reviewed literature from several scholars (Hassan, 2002; Abbo et al., 2003; Yemane and Skjelvåg, 2003; Weller et al., 2012; Doust et al., 2014; Mikić and Mihailović, 2014; Weeden, 2018) gives an impression of the crop's stated cultivation and domestication tradition with highest genetic diversity in Ethiopia (Ellis and Poyser, 2002; Baranger et al., 2004; Edwards et al., 2007) as a variety of *P. sativum* var. *sativum*. As a global food perspective, Ethiopian pea is also recognized as one of the genetically diverse crop used for food improvement in the Mediterranean diet (Alarcón and Aldasoro, 2015; Nováková et al., 2019). There is still evidence from Hodmedod's British Pulses and Grains that Ethiopian highlands are one of the key global sites for crop domestication 10,000 years ago (https://hodmedods.co.uk/blogs/news/abyssinian-peas/). It is also evidenced that there are cultivated Ethiopian pea varietal types (MoANR, 2016; Gebreegziabher and Tsegay,

2018; Tsegay and Gebreegiabher, 2019) and agrarian communities in Ethiopia that are still increasing crop genetic diversity, both via breeding new farmers' varieties of existing crops, and through domesticating altogether new crop species (GebreEgziabher and Edwards, 2012).

This evaluation can be used to discern the future and know what fate holds the datasets for which reliable comparisons are practicable, and those for which limited data are available and help in avoiding future loss, and datasets taxonomic nebulousness events of the crop. Similar cases were reported for other datasets on the implication of poor taxonomy on biodiversity conservation (Ely et al., 2017; Guzzon and Ardenghi, 2018). Supporting to the current findings, geographic and taxonomic biases are recently stated as the bottlenecks to make meaningful conclusions about rates of biodiversity in tropical nations (Amano and Sutherland, 2013; Ely et al., 2017; Collen et al., 2008; GebreEgziabher and Edwards, 2012; García et al., 2017; Nováková et al., 2019). Such findings to our knowledge are the first to demonstrate how conservation measures can be helped by datasets examination. Such examination provides a new way to analyze variability in the Ethiopian pea with global ranking gateways for the taxon of agricultural and economic interest (Zeven and Zhukovsky, 1975; Mikić, 2018). Like to the literatures by García et al. (2017), Cernay et al. (2016), and Doust (2019), gathering legume crops from datasets, the current systematized taxonomic analyses could hint new gathering way of the Ethiopian pea and other grain legumes starting from scarce occurrence data. The datasets and analyses results can further use for spatial and temporal studies of this priority taxon. Datasets based spatial and temporal studies are directed in the distribution study for crops and pastures across Amazonia by Imbach et al. (2015) and the distribution prediction for 98 priority species related to cereal and legume crops from Spanish by García et al. (2017).

Based on the current study it can be suggested that, Ethiopian pea collections with unknown record types may contribute to paradigm of unclear origin (Berg, 2009) and domestication background of Ethiopian pea and the whole pea taxonomy. It was also most likely that the narrow eco-geographical assortment of the preserved specimens, living specimens and cultivated forms of the Ethiopian pea may contribute to specific gene and allele composition, and phenotypic emergence like the cased described by Doust et al. (2014). This is via adaptation or the reverse effect stated by Weeden and Wolko (2001), Konečná et al. (2014), Trnèný et al. (2018), and Weeden (2007, 2018). Moreover, the attribution of Yemen as country of origin, domestication, diversity, and local area of cultivation with Ethiopia of the crop stated by several authors (Ellis et al., 1998; Holden, 2009; Mikić and Mihailović, 2014; Bogdanova et al., 2018; Trnèný et al., 2018) was analyzed as not practically evidenced beyond the literatures adoption. It was also evidenced that Ethiopian pea has been recorded in Ethiopia and Yemen, but occurrence records reported by Maxted and Kell (2009) indicated that Ethiopian pea is found only in Ethiopia. Perhaps most important is far to the north, the Asir Mountains of southwest Saudi Arabia and the highlands of Yemen have biological affinities with the Ethiopian highlands, being as they were at one stage part of the large Ethiopian dome that began to arise some 75 million years ago (Kingdon,1989; Mittermeier et al., 2004). Studies on early agricultural pathways and genomic tools in pea breeding programs respectively indicated that, Ethiopian pea is taxon that is distinctly domesticated (Fuller et al., 2012) and only cultivated in Ethiopia (Tayeh et al., 2015).

## CONCLUSIONS

A Classification and Regression Trees analysis was a good algorithmic tool for evaluation of datasets information on Ethiopian pea collections. It clearly distinguished what the Ethiopian pea collections with the global datasets looked like. It better showed the dissimilarities in scientific names, the crops dispersion in various countries and incomplete record types. This was a one step forward to future studies on productivity enhancement and sustainable utilization of the available Ethiopian pea collections. Most of the Ethiopian pea global collections were with the

scientific name *Pisum abyssinicum* A. Braun. However, the preserved and living specimens in most datasets were subspecies types designated as *P. sativum* subsp. *abyssinicum* (A. Braun) Govoro. Most collections were from Ethiopia (with 4 of the record types) and with cultivated variety (*P. sativum* var. *abyssinicum* A. Braun) followed by Afghanistan. Therefore, it was proposed that the lack of taxonomic clarity and the incomplete records of the world Ethiopian pea collections have severely constrained the improvement, productivity and sustainability of the crop. The current evaluation analyses suggested that there is an urgent need to conserve the crop *in situ* for maintaining in its agrobiodiversity via sufficient documentation at current situation.

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