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NUTRITIONAL QUALITY ASSEMSMENT OF CHICKPEA *(Cicer arietinum L.)* GERMPLASM UNDER WINTER AND SPRING PLANTING

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Nutritional QUALITY ASSEMSMENT OF CHICKPEA (Cicer arietinum L.) GERMPLASM UNDER WINTER AND SPRING PLANTING

Résumé

En raison de la menace du changement climatique et de l'instabilité de la sécurité alimentaire, la famine et les problèmes de santé tels que les carences en minéraux qui sont devenus un problème commun à de nombreux pays, notamment africains. Le pois chiche est une source très importante de protéines hautement digestibles et de minéraux, principalement du zinc et du fer. Avec le potentiel agricole du Maroc, la qualité nutritionnelle du pois chiche pourrait être améliorée par la sélection pour fournir aux agriculteurs des semences de meilleure qualité qui sont pertinentes pour la culture du printemps et d'hiver. La caractérisation nutritionnelle et morphologique de 66 génotypes de pois chiche (Cicer arietinum.L) de type Kabuli fait l'objet de cette étude qui vise à évaluer l'impact des dates de semis de printemps et d'hiver sur la qualité des graines et à identifier les génotypes supérieurs. Les résultats ont montré une légère différence entre les semis de printemps et d'hiver avec une variabilité significative des traits de qualité nutritionnelle en plus du HSW. Ces mêmes caractéristiques sont fortement corrélées à la génétique de la plante, au détriment des caractéristiques morphologiques. Il est intéressant de noter que nous avons découvert une corrélation positive entre la teneur en protéines et en minéraux et le HSW. Sur la base de ces mêmes caractéristiques, outre le rendement en grains, trois génotypes supérieurs ont été sélectionnés (Garbanzo, S130002 et S140147) qui constituent un génotype complémentaire.

Mots clés : Cicer arietinum L. ; pois chiche ; Kabuli ; Génotype

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UM6P

Mohammed VI Polytechnic University (UM6P) is an institution that was established in 2017 in Benguerir with a capital of 15’034’650’900 DHS by his majesty king Mohamed VI within the framework of the urban development project of OCP group. Now directed by Mr.ELHABTI Hicham and It is dedicated to research and innovation in Africa and aims to position itself among world-renowned universities in its fields. The University is engaged in economic and human development and puts research and innovation at the forefront of African development. A mechanism that enables it to consolidate Morocco’s frontline position in these fields, in a unique partnership-based approach and boosting skills training relevant for the future of Africa. Located in the municipality of Benguerir, in the very heart of the Green City, Mohammed VI Polytechnic University aspires to leave its mark nationally, continentally, and globally.

The AgroBioSciences (AgBS) program is a component of UM6P. It is a higher education and practical research structure with a vision of solving the real challenges of African agriculture. Oriented towards Africa, AgBS acts in liaison with a large network of universities and research institutions focusing on the continent in order to link real problems on the ground with current science. Many teams with different scientific background are working under the AgBS structure such as the African Integrated Plant and Soil Research Group (AiPLaS), a multidisciplinary research group that addresses problems of agriculture in Morocco and Africa through hypotheses-driven research. AiPLaS team uses advanced technology and three main expertise, quality, physiology, breeding and computer science in order to boost crop improvement research.

Abstract

Because of climate change threat and the instable food security, health issues like mineral deficiencies and hunger became a common problem for many countries mainly African countries. Chickpea is a very important source of highly digestible proteins in addition to mineral content mainly zinc and iron. With agriculture potential of Morocco, chickpea's nutritional quality could be improved through selection to provide farmers with better quality seeds that are relevant to spring and winter planting. Nutritional and morphological characterization of 66 chickpea genotypes (*Cicer arietinum.L*) of Kabuli type makes the subject of this study which aims to assess the impact of spring and winter planting dates on seeds quality and identify superior genotypes. Results have shown slight difference between spring and winter planting with significant variability of nutritional quality traits in addition to HSW. The same traits are found to be highly correlated to genetics of the plant adversely to morphological traits. Interestingly, we have discovered a positive correlation of protein content and mineral content with HSW and based on the same traits besides grain yield three superior genotypes were selected (Garbanzo, S130002 and S140147) which make a complement genotype.

Key words: *Cicer arietinum* L.; Chickpea; Kabuli; Genotype

Abbreviations

Ar: Area

ANOVA: analysis of variance

Dia: Diameter

FAO: Food and Agriculture Organization

HSW: Hundred seed weight

Len: Length

NIR: Near infra-red

OCP: Office Chérifien des Phosphates

ONSSA: Office national de la sécurité sanitaire des produits alimentaires

Per: Perimeter

Pro: Protein

PC: Principal component

Star: Starch

SCI: Commission Internationale de l'Eclairage

Wid: Width

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Introduction

Climate change and substantial population growth over the past century have resulted in many problems related to low access to sufficient agri-food products. Increasing production and productivity with improved nutritional quality value of the agri-food products could enhance livelihood and build sustainability of food and nutritional security. In Morocco 31.6 % of children are suffering from iron deficiency according [1].statistics uncovered that 1.7 million of the Moroccan population are under-nourishment. Hence, there are many alternatives that could take place of our principal essential nutrients sources. Chickpea could be a good alternative due to its high nutritional value especially protein content and micronutrients concentration. Chickpea was reported to be rich mainly in zinc, iron and highly digestible proteins with essential amino acids content except Sulphur containing amino acids [2]. In Morocco as well as in many other countries in the Central - West Asia and North Africa (CWANA) region, chickpea is being cultivated under two main environments corresponding to spring and winter planting. Despite the success that has been made during the last decades with a significant increase of winter chickpea planting resulting in an increase of both harvested area and production, still many farmers are growing chickpea under spring planting. The lack of new large seeded varieties with good resistance to Ascochyta blight and the consumer's market preferences are the main driver of this trend. Unfortunately, for long time breeders gave more focus to seed yield potential and diseases resistance and somehow neglect the nutritional quality traits.

In this study we intend to:

- Assess the impact of both winter and spring planting dates on seed morphological and nutritional quality traits of 66 Kabuli chickpea genotypes,
- Identify potential superior chickpea genotypes with high nutritional value under winter and spring planting,
- Identify potential genotypes with good quality traits adapted to both winter and spring planting.

Bibliographic research

I. History, origins and taxonomy of Chickpea

The name *Cicer* has a Latin origin, may be derived from Greek Kikus which refers to force or strength as Don (1882) suggested, while Duscack (1871) derived it from Hebrew Kirkes a Hungarian language surname, where Kikar means round, while *Arietinum's* oldest reference belongs to Columilla's work probably as translation of the Greek Krios. Another name for ram and Chickpea implicates the seed shape, similar to a ram's (Aries) head [3].In Great Britain and Anglo-Saxon countries Chickpea is a corruption of Chich-pea, In Arabic countries, it's called Hummus.

The oldest known probable occurrence of Chickpea dated to about 5450 BC (Before Christ), from Hacilar near Burdur in Turkey. Hopf (1969) cites proofs of cultivation at Jericho, big quantities were found in layers dating back to the early Bronze age, 3200 BC [3].

The progenitor wild specie relative to domestic Chickpea is *C.reticulatum*, furthermore, it's believed that domestication of Chickpea has occurred in south-east Turkey. Changes with domestication include loss of dormancy followed by reduced pod dehiscence, larger seed size, larger plant size with more erect habit, and reduced anthocyanin pigmentation, However, the key to chickpea domestication was the transit from a winter habit to a spring habit, which prevented the threat of lethal infestation of the endemic Ascochyta pathogen complex [4].

Chickpea was introduced to the New World in the 16th century AD by the Spanish and Portuguese, and Kabuli types moved to India from the Mediterranean in the 18th century (van der Maesen, 1972) which is considered nowadays one of the largest chickpea consumers. Desi chickpea was mostly imported to Kenya by Indian immigrants during the later 19th century (van der Maesen, 1972) as an African country. Recently chickpea breeding programs began in the USA, Australia and Canada [4].

II. Chickpea Crop characteristics

1. Biology of the plant

Plant physiology

Chickpea "*Cicer arietinum*" is a member of pea and bean family (*Leguminosae/Fabaceae*), one of 43 species in *genus Cicer[5].* It is an annual herb, with a bushy appearance and pubescent surface including roots, stem, pods and leaves, attaining less than 1 meter in height [6].

Taxonomy

- **Kingdom** Plantae
- **Subkingdom** T racheobionta
- **Super division** Spermatophyta
- **Division** Magnoliophyta
- **Class** Magnoliopsida
- **Subclass** Rosidae
- **Order** Fabales
- **Family** Fabaceae (Leguminosae)
- **Subfamily** Faboideae (Papilionaceae)
- **Tribe** Cicereae
- **Genus** Cicer

The plant has three types of branches (Fig1.A) [6]:

- primary branches which are woody with thick cuticle supported by a firm stem.
- Secondary branches arise from primary branch buds, they bear leaves and flowers.
- Tertiary branches, their appearance depends on genotype and growing conditions.

Each leaf contains 5 to 7 pairs of hairy leaflets, opposite or alternate. The root system is characterized by a thick tap with several side roots and a hairy epidermis. The flower could be described as regular, bisexual with five hairy sepals in addition to five petals with a papilionaceous form and ten stamens in a diadelphous arrangement with globose stigma, sessile pubescent ovary containing, while all these elements are attached to a single whorl in calyx form (Fig1.C). Chickpea is highly a self-pollinated plant, while anthers dehisce one day before the flower opens. Generally flowering starts in the range of 24 to 80 days after sowing and continues till moisture depletion. Following that process, pods (Fig1.B) start appearing about six days after fertilization and may take up to four weeks for completing seed development [6].

Figure 1. Morphology of Chickpea plant: Major Plant (A), Seed pod (B), Flower (C)

Seed description

A seed is the part of a plant which is used for propagation. Botanically seed is a matured integument megasporangium, also defined as matured ovule consisting or embryonic together with reserve nutrients surrounded by a protective coat [7]. Chickpea seed is considered as a matured ovule with reserve nutrients surrounded by protective coat.

Chickpea seed is composed of two cotyledons and has a ram's head shape, hence the name "arietinum" in addition to other shapes such as globular or quasi-spheric with a characteristic beak. The surface seed coat may be smooth or tuberculate, while seed size and color depend on chickpea type and environmental conditions, especially moisture and heat [6].

The following figure (Fig.2) illustrates the seed from different sides.

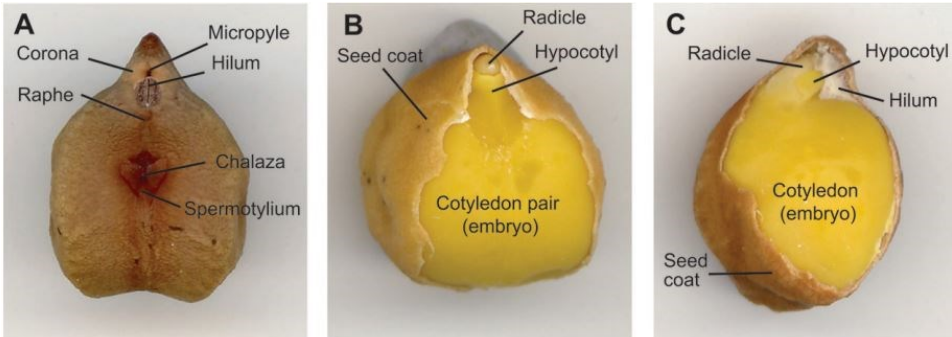


Figure 2. Chickpea seed (Cicer arietinum L.). A, Ventral view showing external features. B, Ventral view with seed coat removed, showing major internal features. C, Lateral view with seed coat removed, showing major internal features, adapted from [8].

There are two types of chickpea Desi and Kabuli (Fig3) that differ by morphological and structural characteristics (Color, size and prominence) with low nutritional value differences.

Desi type has mostly brown color with angular shape and a prominent "beak" on the embryonic axis, while Kabuli type has contrasting characteristics and creamy or white color in addition to rounded shape, also less pronounced "beak". In general, it's heavier than the Desi type. The seed coat is much thinner occupying 5% of total seed weight, compared with 14% in Desi seeds, that explains why Kabuli seed coats are more difficult to remove [8].

A **B** **C**

Figure 3. Desi (A), Kabuli (B) seeds [9], and seed color variation (C) [6].

2. Cultivation ecology of Chickpea

For an excellent vegetative and reproductive development many ecological conditions and agronomic practices should be assessed, like moisture, light, temperature, irrigation…

Chickpea is best sown in a depth of 1 Cm under good humidity conditions [10], otherwise seeds may be sown deeper at an optimum of 5 to 8 cm especially under dry conditions to ensure better moisture conditions [11].

Soil structure vary depending on several field conditions meanwhile some studies have shown that the best seed yields were obtained when the plants were grown in soils with 47% aggregates of more than 2mm diameter, 28% between 1 and 2 mm and 25% less than 1 mm [10] which plays a role in root aeration and moisture and affects yield that is correlated to moisture content according to Nukawan and Dhingra [12].

Different soil requirements are studied in order to define the optimum of required elements, such as alkalinity and salinity that leads to a quite well growth with a conductivity value of 1.2 mmhos $.cm^{-1}$, while high concentrations lower oxygen uptake generate hydric stress [10].

Mineral nutrients have a major role in crop development especially Nitrogen with an optimum of 30 – 40 Kg per ha, phosphorus with amounts lower than 100Kg per ha and Manganese that leads to top yield when it's accompanied with NPK, Mg, Zn and B also 20 Kg per ha of Zinc increase 14% in yield. In organic matter only vegetative growth is influenced [10].

Seeds germinate in darkness, while they failed to do so under light. For a plant, low light alters the physiological behavior of flowers, also considered as one of low yields reasons, on the other hand an experiment on chickpea cultivars showed that most of these reached their maximum photosynthesis rate at light intensity near 0.5 Cal Cm^{-2} min^{-1}, slightly higher rates are expected at higher intensities. Decreased light intensity caused a decrease of dry weight shoot, pod production and number of seeds per pod also 100-seed weight. Besides light intensity, photoperiodism plays a major role on plant development even more than temperature according to Eshel [13], while several experiments showed that long day periods lead to rapid flowering and under short day period plants remain vegetative for a long time and retard the flowering [10].

A fairly wide range of temperature is suitable for Chickpea germination within a range of 15°C to 30°C, with a constant optimum temperature of 20°C, but differences may exist between cultivars, whereas emergence of plantlets lasts longer under 15°C.

Relative humidity was proven to have no effect on vegetative growth, but high relative humidity (80%) delays flowering and lower number of flowers [10].

3. Biotic and abiotic stress

Most of annual yield losses are due to biotic and abiotic stresses. Globally annual yield losses are estimated to 6.1 million tons per year because of abiotic stresses and 8 tons due to biotic stresses [11].

Abiotic stresses are especially caused by drought, heat and cold. Other abiotic stresses specific to some areas are salinity, waterlogging, soil alkalinity and acidity, and nutrient deficiencies and

Toxicities.

Drought

Drought is defined as a water stress, affected by several factors foremost by climatic, edaphic and agronomic factors. Soil residual moisture is a critical factor for chickpea growth and seed emergence specifically flowering and pod setting stages. While chickpea has highest moisture requirements compared to other crops, seed yield losses due to drought range from 30% to 100% [11] depending on genotype and type of drought.

In order to ensure seed maturity chickpea plants adopt different resistance mechanisms such as drought escape through early maturity, dehydration postponement by maintaining water uptake and lowering water loss and dehydrating tolerance, the ability to metabolize at low leaf water [11].

Heat stress

There are two types of heat stress according to the interaction between time and temperature, heat shock when a plant is exposed to high temperatures from few minutes to few hours, apart, moderate heat known for higher temperatures than optimum during the growing season. Heat is considered as a critical element specifically for reproductive phase during gamete development, flowering and podding to reduce duration of flowering and pod filling resulting in yield loss caused by defects in 50% of flowers at a temperature of 30°C and 100% of flowers at a temperatures higher than 30°C for 3 to 4 days [11].

Like it escapes from drought chickpea plants escape from heat stress by early maturity as a resistance mechanism also by radiation energy reflectiveness, usually from leaves. a third mechanism involves accumulation of solutes and heat shock proteins.

Cold related stress

Cold related stress includes either chilling (between 0°C and 12°C) or freezing or below 0°C without snow cover [11] and it affects the membrane stability by modifying proteins and lipids generating loss of membrane integrity. These effects reduce plant growth and increase chlorosis and necrosis also resulting in sterile flowers. Germination and emergence may be retarded by lower temperatures.

Freezing escape is the resistance of autumn-sown chickpea if emergence occurs after the main freezing period. Chickpea avoids intracellular ice formation either by super cooling with ice formation at temperatures above freezing point or osmotic adjustment by the ability of retaining water in the cell with limited effect. A third way to diminish freezing damage is freezing tolerance, the ability of the plant to avoid cell dehydration or increase membrane stability called hardening [11].

Salinity stress

Salinity stress occurs where evaporation exceeds precipitations leading to accumulation of salt in soil surface. Salinity is measured by electrical conductivity, while a soil is saline when conductivity surpasses 2 $Ds.m^{-1}$. Depending on type of molecules saline affected soils are divided into groups as saline (Na_2SO_4 and NaCl, seldom $NaNO_3$), alkaline ($NaCO_3$ and $NaHCO_3$), seldom (Na_2SiO_3 and $NaHSiO_3$), gypsifer ($CaSO_4$ and seldom $CaCl_2$), magnesium and acid sulphate ($Al_2(SO_4)_3$ and $Fe_2(SO_4)_3$). Salinity stress has an impact on the whole plant organs, different signs appear after germination, usually necrosis and anthocyanosises. To resist against salinity stress plants tend to accumulate salts in leaves cells vacuoles or meristematic cells [11].

Despite abiotic stresses chickpea faces more damaging diseases caused by pathogens including fungal diseases (67 fungi) followed by virus (22 viruses) then bacteria (3 Bacteria) and 80 nematodes [14]. The most severe disease is the fungi Aschyota Blight (*Ascochyta rabiei)* , it attacks all above ground part of the plant at all growth stages causing necrotic lesions [15] with a round or elongated shape. On the green pods lesions are often circular with dark margins (Fig4.a), and the plant dies when the lesion gridle the stem.

Another highly destructive fungi is Fusarium Wilt (*Fusarium oxysporum*) which causes wilting withing 25 days after sowing (Fig4.c). The affected chickpea plants show dropping of the leaves and pale color and an internal damaged tissue on the roots precisely the pith and xylem which blocks water transport to the aerial part. It is difficult to control this disease because it's a seed- and soil born and can survive in soil for long periods even without a host [14]. Botyris grey mould (*Botrytis cinerea*) an important and damaging disease of chickpea that affects the aerial part especially flowers and growing tips, usually appears in a water-soaked lesions on the stem which may be completely gridled (Fig4.b).

a **b** **c**

Figure 4. Affected chickpea plants by some diseases; a. Ascochyta blight b. Botyris Gray mould c. Fusarium Wilt. (from TNAU Agritech website)

Although the efforts made in diseases management as protection practices more focus should be directed to developing resistance genes that could be transformed into elite chickpea lines as an effective way to limit the attack of these pathogens.

III. Economic importance in Morocco and worldwide

Since 1962 the global production of grain legumes has increased by 1% per annum [16] and still in progress since 1992 to reach its peak in 2018 with 16.9 million tons (fig 5). Including chickpea that ranks second among pulse crops just after beans with a mean annual production of 11.67 million tons counted from 2013 to 2017 [16]. Chickpea is produced in 57 countries under different environmental conditions while South and South-East Asia dominates in chickpea production with 80% of regional contribution. India is the largest producer of chickpea accounting for 65% of total chickpea production, afterward comes Australia with 14%. According to 2020 FAO rankings 11 million tons was registered for Indian chickpea production followed by Turkey, Pakistan, Myanmar and Ethiopia the largest producer of chickpea in Africa (Fig 6).

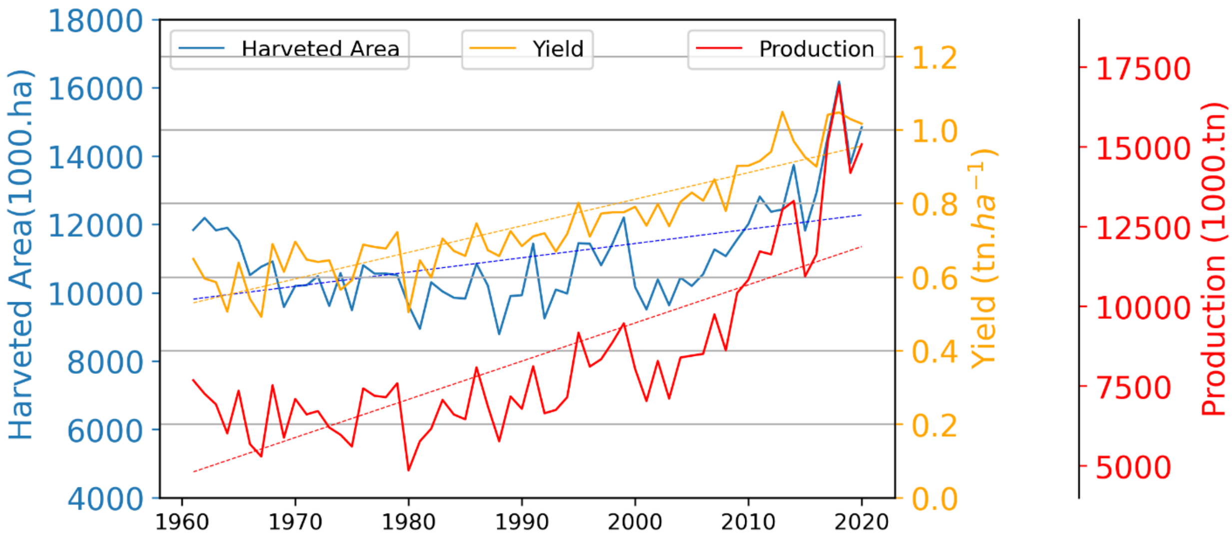


Figure 5. Production, yield and harvested area variation of chickpea worldwide since 1962 to 2020 *[17]*.

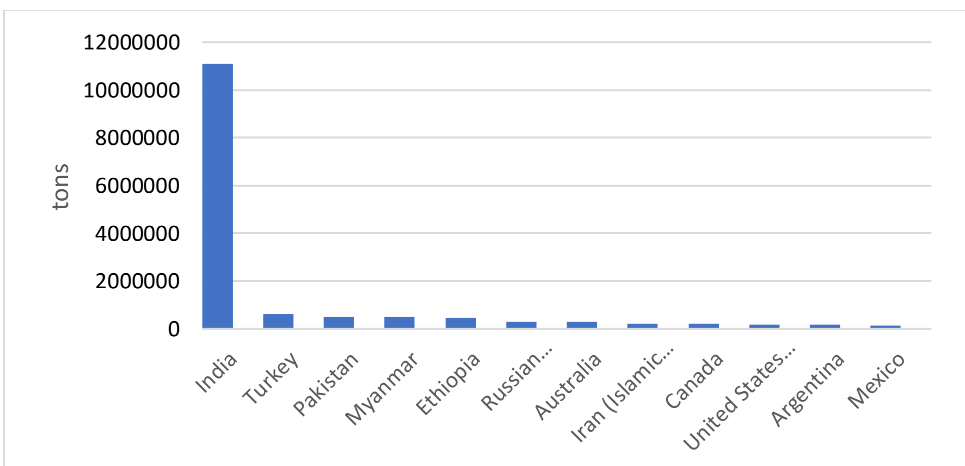


Figure 6. Top 10 countries producing chickpea in 2020 according to FAO rankings.

Although it's the largest chickpeas producer, India is considered as the biggest importer of chickpea worldwide with an estimated mean import of 590,656.8 tons from 2012 to 2016, followed by Bangladesh with 208,308.4 tons and Pakistan ranked third with 104,035.8 tons [16]. On the other hand, Australia meets half of world exports demand and provides over 926,802 tons to the Market annually. India the major producer and importer ranked third after Russian Federation. Mexico is one of major chickpea exporters ranked fifth, known for large production of high quality and large seeded Kabuli types. Kabuli types accounting for 20% of production though it's more distributed worldwide outside of south Asia because it's less expensive and easier to produce. Instead of

Kabuli type, Desi type remaining for 80% of world production is more consumed especially in Asian and Australian countries [16].

In Morocco chickpea is the second major food legume after faba bean, cultivated in rainfed and intermediate regions like Taza-Al Hoceima-Taounate (27%), Meknès-Tafilalet (16%), Fès-Boulemane (12%) and Gharb-Chrarda-Benihssen (24%) [18] with a total cultivation area of 53,599 ha and 9275 $hg.ha^{-1}$ of yield in addition to a production of 49,714 tons registered in 2020, a drop fall that came after an important production of 2019 which was the highest amount since 1976 whereas the highest production of chickpea in Morocco belongs to the year of 1974 with 163,790 tons (Fig7)

Even with large agricultural areas, Morocco doesn't produce enough annual quantities that satisfy population needs, whereas productivity and harvested area are in decrease (Fig7) because of low use of certified seeds, low investment in cropping techniques [19] and several biotic and abiotic constraints, mainly climate change, parasites (especially *Ascochyta blight* and *Fusarium oxysporum)* and weed infestation. The challenge here is to find varieties with varied traits like drought tolerance, resistance, high yield and high quality seeds [18].

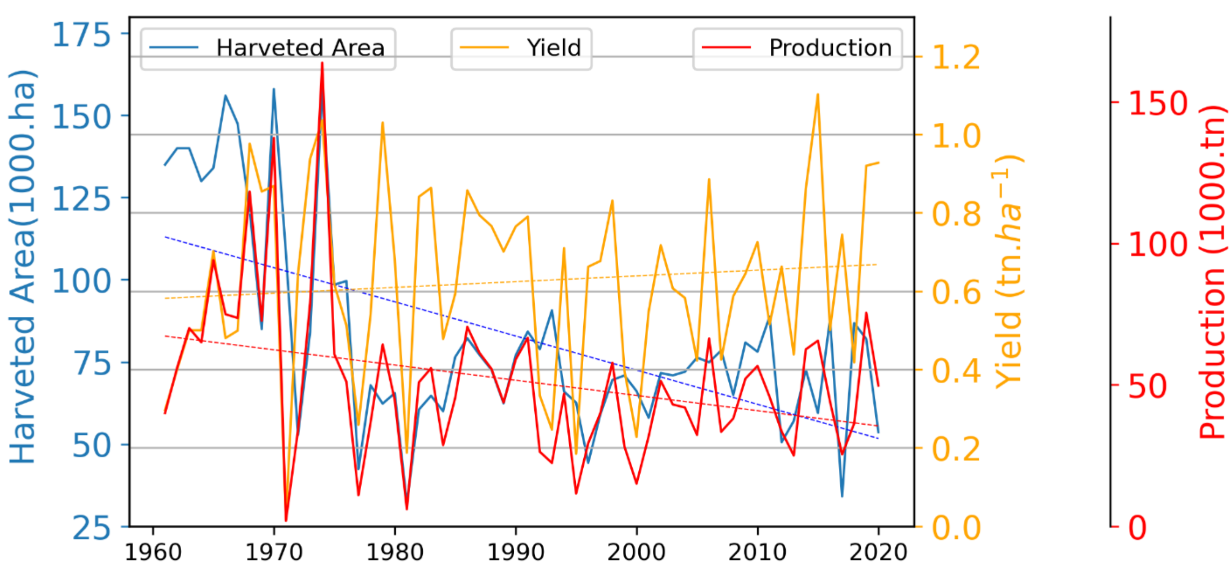


Figure 7. Productivity, yield and harvested area variation of chickpea in Morocco [17].

There are eighteen chickpea varieties registered in Morocco (Table 1), which are divided into two groups based on their cultivation season, Spring and Winter chickpea. Spring chickpea is sown in early March while winter chickpea is sown in December. Studies proved that winter sown chickpea has many qualities as a solution against drought stress and to take advantage of rainfall and moisture availability for better yield compared to spring planted chickpea besides its high maturity as it matures by four to six weeks earlier. Winter planted chickpea has a yield average of 3 tons per ha against less than 0.7 tons per ha for spring planted chickpea (Kostrinski 1974). Despite these advantages, farmers prefer the spring planted chickpea sown in conditions with less soil water availability and higher temperatures because of the small size of winter seeds also to avoid many diseases that occur in winter period and generate heavy costs.

Table 1. Chickpea varieties registered in Moroccan official catalog [20]

Varieties	Year of registration
Amit	2000
Arifi (Flip98-50c)	2009
Ayala	1997
Bouchra (Flip97-114c)	2015
Chakouf (Flip97-190c)	2009
Douyet (F84-92c)	1992
Eulalia	1998
Farihane (F84-79c)	1994
Galit	2000
Hadas	1997
Ilc 195	1987
Ilc 482	1987
Moubarak(F84-182c)	1994
P 34	1997
P 37 (Mazozia)	1997
P 46 (Taiba)	1997
Rizki (Flip 83-48 C)	1992
Zahor (F84-145c)	1994

IV. Nutritional quality of Chickpea

Chickpea’s nutritional value is much diversified among other legumes as an excellent source of proteins which are 2 to 3 times higher in concentration than cereals [21], carbohydrates, fibers, minerals and vitamins, as shown on the table below (Tab2). Only proteins and carbohydrates constitute together 80% of total dry seed weight [22].

Chickpea contains a high proportion of better protein quality especially for Kabuli type [23], also starch, the principal carbohydrate constituent and more or less fat, in addition to high levels of minerals and vitamins especially Potassium, Phosphorus and Folic acid. Fatty acids in Chickpea are diversified, with dominance of Linoleic and Oleic acids, while humans depend on essential fatty acids, Linoleic (omega6) and Linolenic acid (omega3) are considered as the most important fatty acids found in chickpea. Sucrose, stachyose and Raffinose are the main sugars found in chickpea seeds.

Table 2. Chemical composition and nutritive values in mature grains of chickpea [9]

composition/element	Kabuli type	Desi type
Proximities (g 100g-1)		
Protein	17.9-30.8	20.3-27.5
Starch	38.2-43.9	33.1-40.4
Amylose (% of total starch)	24.4-29.2	20.5-25.9
Fat	5.5-6.9	4.4-5.9
Acid detergent fiber	3.0-5.7	12.7-13.5
Neutral detergent fiber	4.2-7.7	10.1-13.6
Minerals (mg 100 g-1)		
Calcium (Ca)	80.5-144.3	115.0-226.5
Copper (Cu)	0.7-1.4	0.5-1.4
Iron (Fe)	4.3-7.6	4.6-7.0
Potassium (K)	816.1-1580.1	1027.6-1479.1
Magnesium (Mg)	152.9-212.8	143.7-188.6
Manganese (Mn)	2.3-4.8	2.8-4.1
Phosphorus (P)	294.1-828.8	276.2-518.6
Zinc (Zn)	3.6-5.6	2.8-5.1
Vitamins (mg 100 g-1)		
Ascorbic acid (C)	0.28-2.40	0.67-3.01
Thiamin (B1)	0.39-0.78	0.22-0.34
Riboflavin (B2)	0.10-0.34	0.16-0.24
Niacin (B3)	0.48-1.49	1.43-2.28

Folic acid (μg/100g)	153.8-486.5	109.0-294.4
Fatty acid (% in oil)		
Palmitic (C16:0)	8.52-10.30	8.56-11.05
Stearic (C18:0)	1.21-1.68	1.04-1.60
Oleic (C18:1)	27.70-42.46	18.44-28.51
Linoleic (C18:2)	42.25-56.59	53.13-65.25
Linolenic (C18:3)	2.23-3.91	2.54-3.65
Sugar (g 100g-1)		
Sucrose	3.10-4.41	1.56-2.85
Raffinose	0.48-0.73	0.46-0.77
Stachyose	1.76-2.72	1.25-1.98
Verbascose	Not detected	Not detected
Oligosaccharides (raffinose + stachyose + verbascose)	2.32-3.44	1.72-2.75
Phytic acid (g 100g-1)	0.78-1.25	0.63-1.24

Compared to other grain legumes, chickpea is considered as a good source of minerals required by humans as iron, Zinc, selenium and sodium. Chickpea composition meets the adult requirements of essential amino acids except methionine, cysteine and cystine [22]. Chickpea is rich in water soluble vitamins like B complex vitamins and vitamin C as well as lipid soluble vitamins mainly vitamin A, vitamin E and vitamin K.

The major nutrient proportions are concentrated in cotyledons, otherwise the seed coat contains much of non-digestible carbohydrates and a high proportion of Calcium [23]. Proportions of nutrients vary based on environmental conditions like irrigation, climate and soil type also type of seed.

Table 3 shows small differences between Desi and Kabuli type in term of nutritional value except for many elements like Calcium and dietary fibers which are more concentrated in Desi type due to a thicker coat where fiber content and calcium concentrate, in contrast Kabuli is preferred in term of calorific value. High content of dietary fiber has a negative effect on absorbance of nutrients especially monogastric animals which limits the rapid growth in live stocks and leads to some nutrient deficiencies in malnourished populations. On the other hand, fiber diets have many benefits for people with obesity, diabetes and heart diseases.

Alongside nutritional elements, Chickpea holds some antinutritional factors like protease inhibitors, amylase inhibitors, oligosaccharides and polyphenols, these components contribute in lowering the nutritional value. There are three toxic factors which are Phytolectins, cyanogens and mycotoxins [24].

These major components should be taken in consideration for some standard requirements, and health benefits. The only disadvantage of chickpea consumption is the flatulence caused by production of high amount of CO_2 in the intestine, it's due to α-Galactosides carbohydrates, mainly Raffinose [9].

Table 3. Antinutritional and toxic factors in Chickpea seeds [24].

Constituent	Number of cultivars tested	range	Mean
Protease inhibitors			
Trypsin (units/mg)	15	6.7-14.6	10.9
Chymostrypsin (units/g)	15	5.7-9.4	7.1
Amylase inhibitors (units/g)	16	0-15.0	8.7
Oligo saccharides (g/100g)			
Raffinose	16	0.36-1.10	0.52
Stachyose	16	0.82-2.10	1.31
Stachyose + Verbascose	4	1.90-3.0	2.41
Polyphenols (mg/g)			
Total phenols	22	1.55-6.10	3.03
Tannins	5	Traces	-
Phytolectins (units/g)	1	400	400
Cyanogens (Glycosides)	3	Traces	-
Mycotoxins (ppb)	3	Traces-35	18

V. Chickpea industry and traditional food

Increasing demand on healthy food made chickpea an important ingredient in diet of millions of people, in response to that food industries are inventing new products based on or incorporating chickpea like snacks, pastes, bread and peanuts, following varied forms of processing that uses different chickpea aspects such as roasted, boiled or milled form.

The main challenge in using seed proteins in food industry is to replace organoleptic properties of animal proteins like appearance, texture and mouthfeel. Thus, functional properties of chickpea seeds are important in defining the relevant process to obtain a desired final product. Throughout the years several processing methods have been used to meet the consumer demands such as extrusion in order to decrease the potential of undesirable hardening of the product, also roasting is a common processing method used to maintain the shape and crunchiness of chickpea. Different drying methods are used depending on the desired application of chickpea, but conventional drying is more frequently used in food industries due to cost manners. For higher nutritional value and less antinutritional factors germination and fermentation are applied to chickpea since it experienced increased essential amino acids concentration and enhanced antioxydant activity. Moreover, other methods are applied in food industry like boiling, microwave cooking and autoclaving also enzymatic processes.

The following table illustrates the most important traditional preparations around the world, some of them make part of authentic food of several Mediterranean countries like Lebanon, Jordan and Palestine. In Arabic countries it’s mostly consumed in Ramadan where they prepare different dishes based on chickpea like Tashrib (Fig8.h), a soup from Baghdad including chickpea with pieces of meat. In Syria more than 75% of chickpea is consumed in form of Hummus-bi-tahineh, tisquieh (Fig8.g) and falafel (Fig8.f) [25], while the first dish’s origins are from Lebanon, but most of them are the same in different countries mainly Jordan Iraq and Lebanon. Instead of plates, chickpea can also be made into a hot drink (Fig8.i) like coffee and tea.

For Maghreb countries chickpea makes part of a culinary dish in Tunisia called Lablabi (Fig8.b), boiled chickpea with a mixture of spices served with Tuna, bread and pepper [26]. Also in Moroccan Sahara varied couscous (Fig8.d) dishes were developed which are containing chickpea as an ingredient with meat and vegetables served over decorticated wheat or barley grains, the best known is couscous of five seeds named couscous El-khomassi [26]. In Morocco mainly Oujda city there is a popular dish totally based on chickpea flour named ‘Karan’ (Fig8.a), it’s a mixture of chickpea flour eggs and oil. Chickpea makes a part of Maghreb countries soups mainly Hlalem (Fig8.c), a Tunisian soup and a Moroccan soup called Harira (Fig8.e) mostly made in Ramadan and contains different ingredients especially chickpea, lentil, pieces of meat and cereal paste with a mixture of spices. Rather than chickpea usage as an ingredient it's also cooked in different forms especially in Morocco like puffed or boiled chickpea consumed with spices and salty roasted chickpea.

Figure 8. Pictures of different dishes based on chickpea prepared in many countries took from Google image.

Chickpea is also used as an effective source of energy for animal feed due to the high values of proteins and fat, especially for ruminants and it's desirable to reduce in antinutritional factors and fiber content for non-ruminants to maximize the nutritional benefit. Experiments conducted on 30 days old rabbits fed with 10% to 20% of chickpea incorporated in their food has shown a digestible energy concentration that varied from 3100 to 3200 Kcal/Kg [27].

Table 4. some traditional preparations of chickpea around the world [25].

Food	Component	Method	Country
Dhal	Decorticated dry split Cotyledons	Boiled in water to a soft consistency, fried with spices and consumed with cereals	**Bangladesh, India, Nepal and Pakistan**
Chhole	Whole seed	Prepared and consumed similar to above	**Afghanistan, Bangladesh, India, Iran and Pakistan**
Pakora	Besan (dhal flour)	Besan is fried in oil and consumed as a snack	**Egypt, India, Iran, Pakistan and Sudan**

Kadi	Besan	Besan is boiled with butter milk and used as curry	**Indian subcontinent**
Unleavened bread	Whole seed/besan	Chickpea flour is mixed with wheat flour and roti is prepared	**Ethiopia, India, Pakistan and Syria**
Kiyit injera	Whole seed	Fermented	**Ethiopia**
Roasted	Whole seed	Grains are heated at 245–250°C for 2 min	**Afghanistan, Ethiopia, India, Iraq, Iran and Nepal**
Homos-Bi-tehineh	Whole seed	Soaked, boiled and mixed with other ingredients	**Egypt, Jordan, Lebanon, Syria, Tunisia and Turkey**
Tempeh	Decorticated split seed	Fermented product	**Canada and the USA**
Leblebi	Whole seed	Boiled in water with salt and pepper	**Jordan, Tunisia and Turkey**
Dhokla	Besan	Fermented with green gram flour	**India**
Green immature seeds	Whole green seed	Raw, salted or roasted	**Ethiopia, India, Iran, Nepal, Pakistan and Sudan**
Salad	**Whole seed**	**Boiled in water and served with other vegetables**	**Australia, Canada, Mexico, Spain and the USA**

Materials and methods

I. Plant material

A collection of 66 genotypes of chickpea including 63 genotypes of large seeds and 3 varieties (Arifi, Garbanzo, Mubarek) used as checks, were used for the experiment conducted in 'Marchouch' under spring (February 26th, 2019) and winter (December 25th, 2018) planting according to an Alpha Lattice design with three replications.

II. Seed morphological characterization

Morphological parameters were measured using an OPTO Machine (Fig.9.a) for every seed in every image. The machine is equipped with a camera of high resolution for imagery, a balance with high sensibility and a software for image processing with an algorithm. Random samples of 100–200 grains were obtained from the harvest of every plot and were scanned. The images collected were analyzed using Opto-software and the morphological characteristics of every grain in every image were obtained. Grain characteristics include HSW(g) and shape parameters of seeds including length(mm), width(mm), seed area(mm^2), circularity, eccentricity, rugosity, finesse, diameter(mm), perimeter(mm), compacity, inside length(mm), Crofton perimeter(mm) and area difference centrale(mm^2).

In order to get color features of seeds based on absorbance of light we used the KONICA MINOLTA CR-5 machine (Fig.9.c). It separates hue, value and saturation into independent dimensions according to the CIE reference L*a*b* system. L* defines a range of value that goes from 0 to 100, in other way lightness that goes from white to black color. a* is a range of colors from red to green while b* ranges from blue to yellow, both are between negative and positive values. Hue (h*) and saturation(C*) are calculated by combining both parameters a* and b* on the CIELAB color space diagram. Whereas saturation or chroma is represented from the center of diagram and hue is the angle of chromaticity otherwise they can be extracted from the following formulas [28] $C^* = (a^{*2} + b^{*2})^{1/2}$ $h^* = \arctan$

III. Seed Nutritional quality analysis

Nutritional quality evaluation of proteins, starch, ash, fat, moisture and fiber were determined using near-infrared spectroscopy (NIRS, DS 2500, Foss). The physiochemical parameters were obtained using an in-house developed calibration with high correlation values (r = 0.97) between the predicted and analytical values. (Fig.9.b).

To analyze micronutrients concentration (Iron and Zinc) in mg/Kg, X-RAY analysis was conducted using X-Supreme 8000 machine (Fig.9.d) which consists of four components: an excitation source, sample, detector and a data collection also an analyzing system. Whereas the excitation source emits x-ray light toward sample. Hence, sufficient energy ejects an electron from an atom leaving a vacancy then adjusted by replacing another electron to a lowest energy level. That process creates an x-ray which characterizes specific electron transition for that element, then transformed into information based on calibration models.

a b c d

Figure 9. Quality analysis machines: a.Grainscan ; b.NIRs ; c.Colorimeter ; d.Xray.

IV. Statistical methods

Predicted means of each three repetitions were calculated based on 'Blue' in order to get single values for each genotype. ANOVA test and heritability were performed in order to get the significance of variables and the effect of genetic/environment on genotypes using 'MetaR' program. Whereas PCA and correlations also linear regressions were constructed by Rstudio using 'FactoMineR', 'factoextra' and 'PerformanceAnalytics' packages. Meanwhile, the coefficient and the p-value of the correlations are based on Pearson's correlation. Summary data was reported as mean, maximum, minimum and percentiles, generated by SPSS and using the same program in order to study the effect of weather on variables we proceeded automatic linear modeling function and genotype/environment interaction analysis was calculated using mixed model function.

Results

I. Descriptive analysis

1. Descriptive analysis of spring planted genotype collection

Table_5 represents descriptive analysis including min, max, means and percentiles of morphological and nutritional quality traits for all genotypes. Considering morphological traits, means show that length is bigger than width by 1.34 mm and percentiles revealed more variability of values for HSW and area. The range of maximum to minimum values was larger for HSW, area and diameter with 21.36g to 56.34g, 44.98mm to 64.61mm and 7.55mm^2 to 8.98mm^2, respectively. while there was no significant difference observed between genotypes for length. Whereas for nutritional quality traits, mean values revealed that protein has the biggest value among the other nutritional variables accounted for 23.51% followed by fiber and fat then ash and starch with 19.52%, 6.45%, 6.30% and 5.41%, respectively. Moreover iron values are bigger than zinc with a mean of 66 mg.Kg^{-1} against 45.91 mg.Kg^{-1} . There is a variability of values between genotypes considering iron, zinc, protein, fat and fiber adversely to ash and starch.

Table 5. Descriptive analysis of morphological and nutritional quality traits for spring planting.

HSW(g); Length(mm); Width(mm); Area(mm^2); Perimeter(mm); Diameter(mm); Protein (%); Fat (%); Fiber (%); Ash (%); Starch (%); Fe (mg.Kg^{-1}); Zn (mg.Kg^{-1}).

2. Descriptive analysis of winter planted genotype collection

Table_6 summarizes descriptive analysis of morphological and nutritional variables which belongs to 66 genotypes planted under winter environment. Regarding morphological characterization, means show that length is larger than width by 1.35 mm while percentiles revealed that HSW and area have more variability, moreover, seeds don't differ in term of length which ranges from 8.92 mm to 8.95 mm. Minimum and maximum values indicate larger ranges for HSW, area and diameter. Concerning nutritional quality variables protein makes the biggest proportion among analyzed nutrients accounted for 23.59% followed by fiber and fat then ash and starch with proportions of 19.59%, 6.45%, 6.29% and 5.41% respectively. percentiles show more diversity of values for protein, fat, iron and zinc, whereas, according to minimum and maximum values there is almost no difference between genotypes in term of ash which ranges from 6.02% to 6.54%.

Table 6. Descriptive analysis of morphological and nutritional quality traits for winter planting.

HSW(g); Length(mm); Width(mm); Area(mm^2); Perimeter(mm); Diameter(mm); Protein (%); Fat (%); Fiber (%); Ash (%); Starch (%); Fe ($mg.Kg^{-1}$); Zn ($mg.Kg^{-1}$).

II. Relative change between spring and winter planting

Relative change was calculated using the formula $\frac{winter\ value - spring\ value}{winter\ value} \times 100$ for each genotype, in order to get the difference percentage of variation between winter and spring planted genotypes.

Figure 10 represents range of relative change values for each variable and it indicates that greater number of winter genotypes have bigger values of fat, fiber and iron while maximum percentage of difference is greater for spring genotypes concerning HSW, fat, starch, a*, iron and zinc adversely to diameter, area and width. Whereas length and perimeter reveal no difference between genotypes among environments.

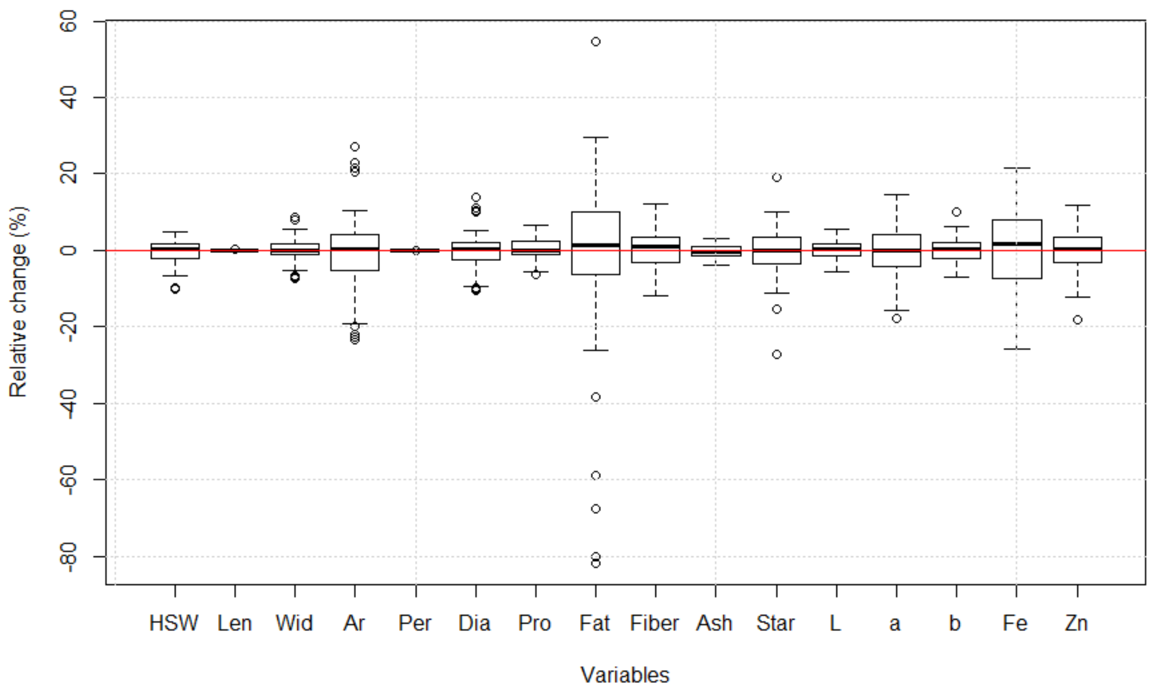


Figure 10. Relative change between variables of spring and winter planted genotypes

III. Significance of variance, coefficient of variation and heritability test for spring and winter planted genotypes variables

Table 7 and 8 summarize each of ANOVA, coefficient of variation and heritability tests to study significance of variance, dispersion of traits values and to measure how much a trait is related to genetics of the plant and to environment conditions.

1. Spring planting

Regarding spring planted genotypes, Coefficient of variation of fat, area and iron are accounted for 19.03%, 11.90% and 13.26%, respectively. which indicates wider dispersion of values in comparison with the other traits, moreover, dispersion of perimeter and length values belonging to 0.02% and 0.10% was the lowest.

According to Anova test, protein, fat, fiber, ash, starch, iron and zinc as nutritional quality traits in addition to HSW are accounted for being very highly significant (p-value < 0.001). Hence, none of the morphological traits excluding HSW are significant (p-value > 0.05). Heritability shows that the same significant variables are more controlled by genetics instead of environment, while HSW, protein, fat, fiber, ash and iron are more heritable for crossing above 85% of heritability.

Table 7. Anova, CV and heritability of morphological and nutritional quality traits for spring planting.

2. Winter planting

Regarding winter planted genotypes, Coefficient of variation of fat, area and iron is accounted for 20.20%, 10.66% and 13.87%, respectively which indicates similarly to spring planted genotypes wider dispersion of values in comparison with the other traits, while dispersion of perimeter (0.02%) and length (0.09%) was the lowest.

Concerning Anova test, all nutritional quality traits in addition to a* and HSW are very highly significant (p-value < 0.001) while each of width, area, perimeter, diameter and a* are moderately significant (0.01<p-value<0.05). Likewise, spring results, heritability in winter experiment was also higher only for nutritional quality traits and HSW.

Table 8. Anova, CV and heritability of morphological and nutritional quality traits for winter expirement.

IV. Environment impact on different traits of genotypes

1. Identification of environment impact on genotypes throughout Gene_environment interaction test

Genotype / environment interaction test results are summarized in table_9, they were generated using a mixed model function on SPSS and we aim to identify whether environment change has an effect on traits of genotypes. Significance shows no important interaction though there is a moderate significant interaction for area, diameter and fiber accounted for p-value of 0.04, p = 0.05 and p = 0.04, respectively.

Table 9. Gene-environment interaction analysis of morphological and nutritional quality traits.

2. Identification of environment impact on variables throughout correlation between similar variables of different experiments.

In term of regression between similar variables of different experiments presented in figure_11, HSW and protein show a strong correlation in a positive way with R equal to 0.98 and 0.89 respectively followed by starch, fat, fiber, Fe and Zn, while a* parameter shows a moderate correlation that reaches 0.4. whereas the other trait regressions including diameter, length, perimeter, width, b* and L* have no correlation.

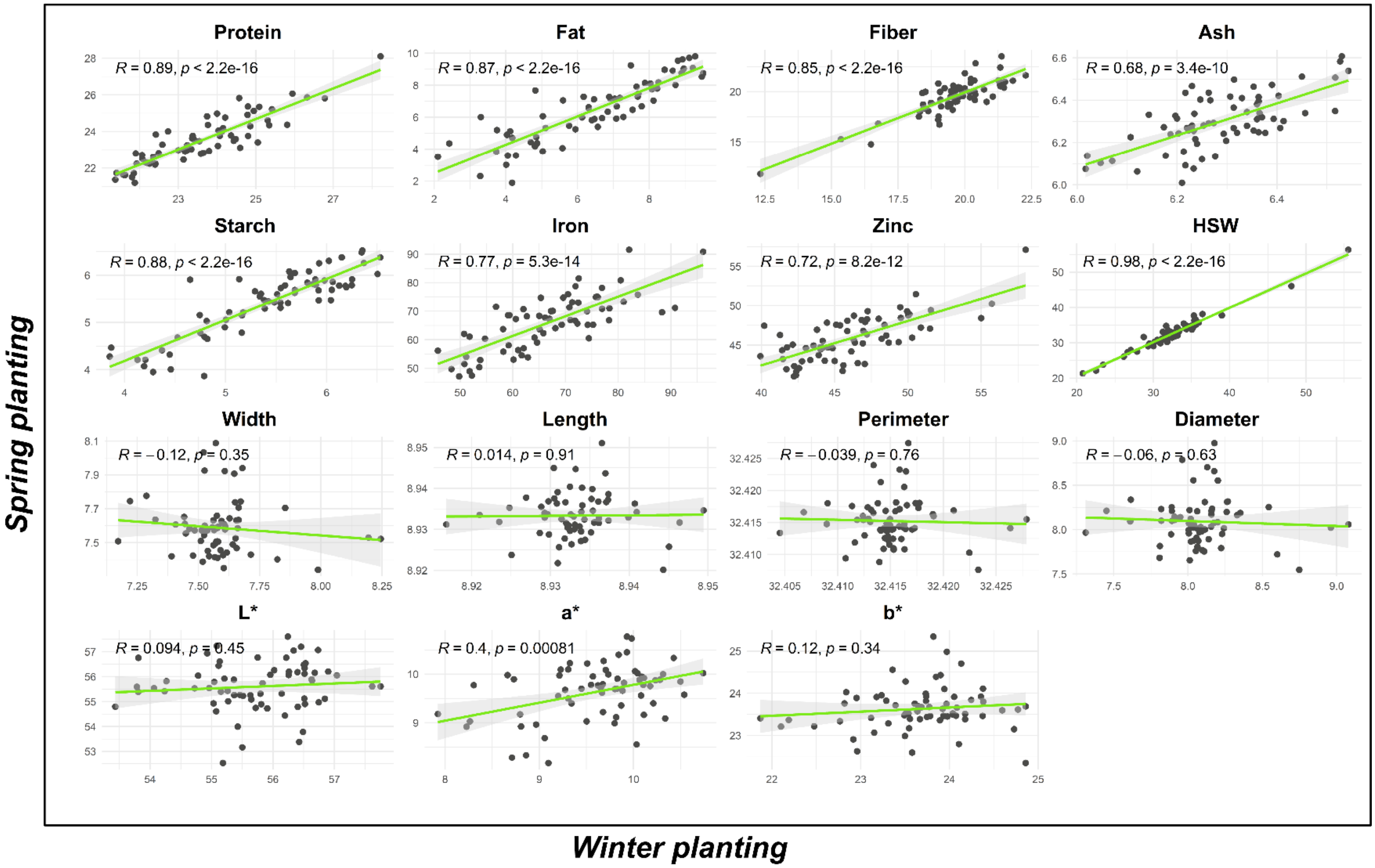


Figure 11. Regression of each trait, between spring and winter planting.

V. Identification of interconnection between traits for spring and winter planting.

1. Correlation between each two variables for spring and winter planting.

Correlations between variables were performed based on Pearson's correlation using Rstudio and they are summarized in figure12. We would like to identify how traits behave or vary in comparison with other tarits.

For both experiments we recognize a highly significant correlation between length, width, area, perimeter, diameter and the same for proteins, fat, fiber, ash and starch apart the correlation between fat and fiber, in addition to Color traits which are also correlated significantly between each other (Fig.12). In regards to spring experiment, HSW is significantly correlated with protein (R = 0.32), and fiber (R = -0.38) and slightly with starch (R = -0.28) and Zinc (R = 0.30). while a* is significantly correlated with starch (R= 0.34), fat (R= -0.36), and slightly with ash and protein with R equal to 0.34, -0.36, 0.28 and -0.17 respectivley. Whereas Fe and Zinc correlate strongly between each other, thus iron has a negative moderate correlation with fat and protein (R = -0.36 and R = -0.31) and a positive correlation with starch and fiber. Concerning winter experiment HSW is significantly correlated with fiber(R = -0.41) and starch(R = -0.24), slightly with protein(R = 0.29) and zinc(R = 0.29). a* correlates moderatley in a positive way with starch (R = 0.31). In term of minerals iron correlates with fat and protein in a negative way, whereas, Zinc correlates slightly with hundred seed weight and fiber.

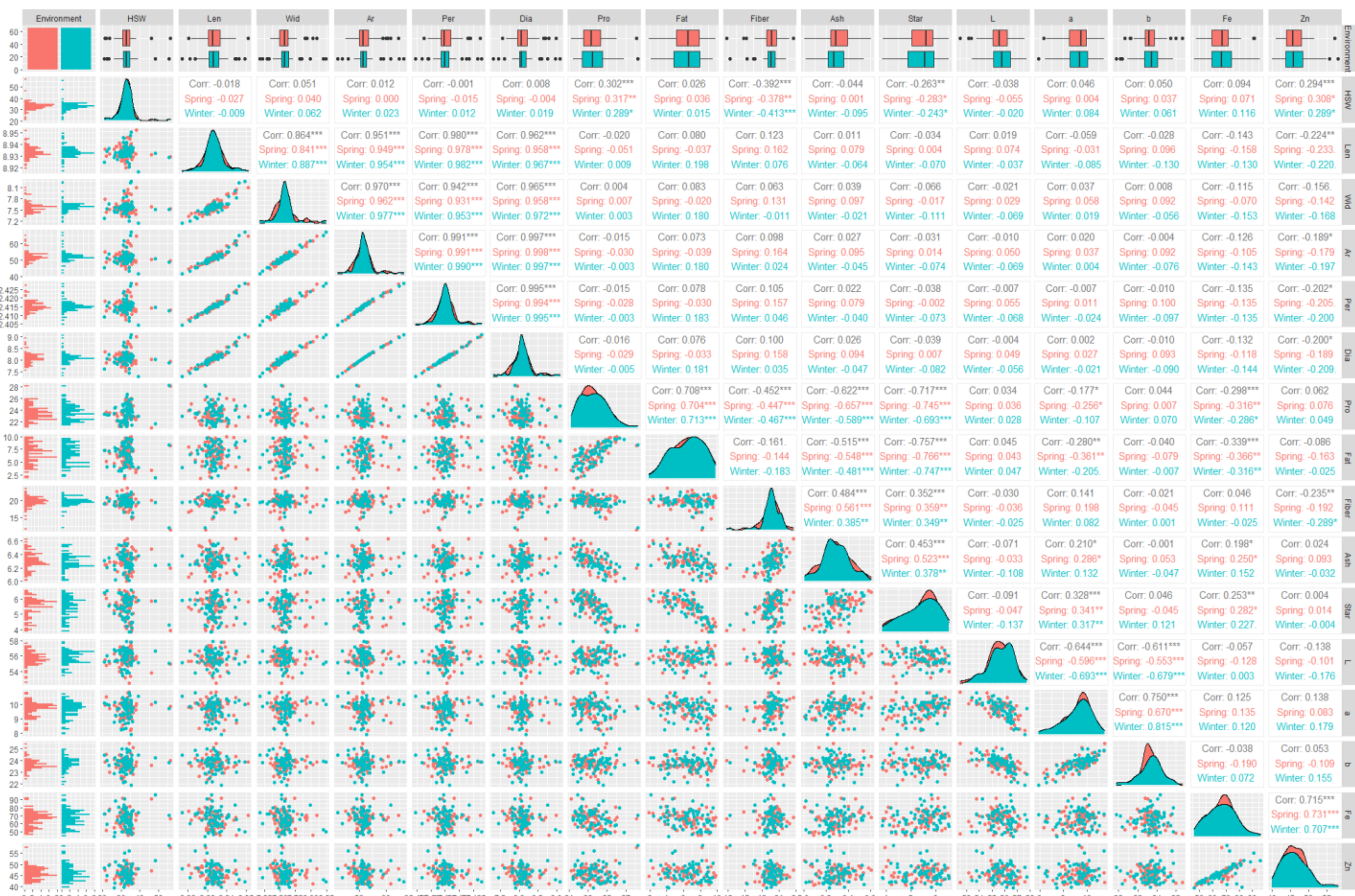


Figure 12. Correlation between traits under spring and winter planting.

2. Multivariate correlation (principal component analysis (PCA))

Principal component analysis presented in figure 14 was performed on Rstudio using ‘FactoMineR’ and "factoextra" packages. our objective is to identify which traits are influencing the answer, taking in conseridertion the correlation between them and also to identify genotypes that are belonging to the same cluster.

As table 10 summarize, for spring planting experiment, the first two principal components explained 53.96 %. PC1 and PC2 accounted for **31.13**% and 22.83% while PC3 explained 13.28% of variation. Regarding winter experiment the first two principal components expalined 52.25% while PC1 and PC2 were accounted for **31.73**% and 20.53% with PC3 making 15.75%. Variable categories contribute the same way in principle compnents comparing between both experiments except zinc and color parameters, while length, width, area, perimeter and diameter show the highest contribution in PC1 as morphological traits and protein, fat, iron, fiber, ash and starch contribute more in PC2. For both experiments, PC3 holds HSW, L*, a*, b* and zinc only for winter planting experiment while it has a low contribution in PC1 for spring experiment which makes the only difference between the two experiments in term of contributions.

For spring planting, size traits correlate strongly and positivley with PC1, in addition to L* they correlate slightly in a negative way with PC2. a*, b*, fiber, starch and ash are positivley correlated to the first two components while hundred seed weight, protein, fat correlate negativley to PC1 and PC2. Iron and zinc correlate negativley to PC1 and positivley to PC2. Regarding winter planting, size traits are correlated to both first components while fiber is correlated only to PC2, whereas, hundred seed weight, protein, fat and L* correlate negativley to PC2 and positivley to PC1 oppositley to ash, starch, a*, b* and iron. Only zinc correlates negativley with both principale components.

With regard to individual clustring, genotypes were clustred into three groups for both experiments, a red highlited cluster with important morphological traits in addition to a blue and green highlited cluster with more important nutritional quality. Interestinegly the green cluster assembles genotypes with the same profile in term of HSW and protein but situated in the opposite of starch and mineral traits. Moreover, multiple genotypes have maintained the same quality since they were found in the same green cluster for both experiments and these genotypes ranked by the variety Garbanzo are summarized in the following figure(Fig.13).

Table 10. Variables contribution in the first three principal components.

	Spring			*Winter*		
	PC1	**PC2**	**PC3**	**PC1**	**PC2**	**PC3**
HSW	0.09	1.48	**4.16**	0.01	2.38	**5.54**
Len	**18.36**	0.30	0.04	**18.03**	0.69	0.00
Wid	**17.67**	0.26	0.10	**17.76**	0.73	0.36
Ar	**19.52**	0.21	0.01	**18.73**	0.91	0.19
Per	**19.52**	0.31	0.00	**18.78**	0.92	0.09
Dia	**19.60**	0.25	0.00	**18.90**	0.86	0.10
Pro	0.33	**19.94**	2.76	0.36	**21.59**	3.96
Fat	0.19	**17.91**	0.14	2.14	**16.24**	0.96
Fiber	1.34	**7.20**	2.42	0.00	**9.12**	4.22
Ash	0.67	**15.47**	0.67	0.40	**12.84**	1.65
Star	0.16	**19.28**	1.73	0.99	**19.94**	0.39
L	0.03	1.57	**29.27**	0.00	3.40	**22.19**
a	0.14	7.82	**24.77**	0.28	6.28	**23.63**
b	0.39	0.50	**33.07**	0.44	1.68	**26.59**
Fe	0.48	**6.57**	0.11	1.50	**2.39**	1.54
Zn	**1.52**	0.91	0.75	1.68	0.03	**8.59**
Percentage variation (%)	**31.13**	**22.83**	**13.28**	**31.73**	**20.53**	**15.75**

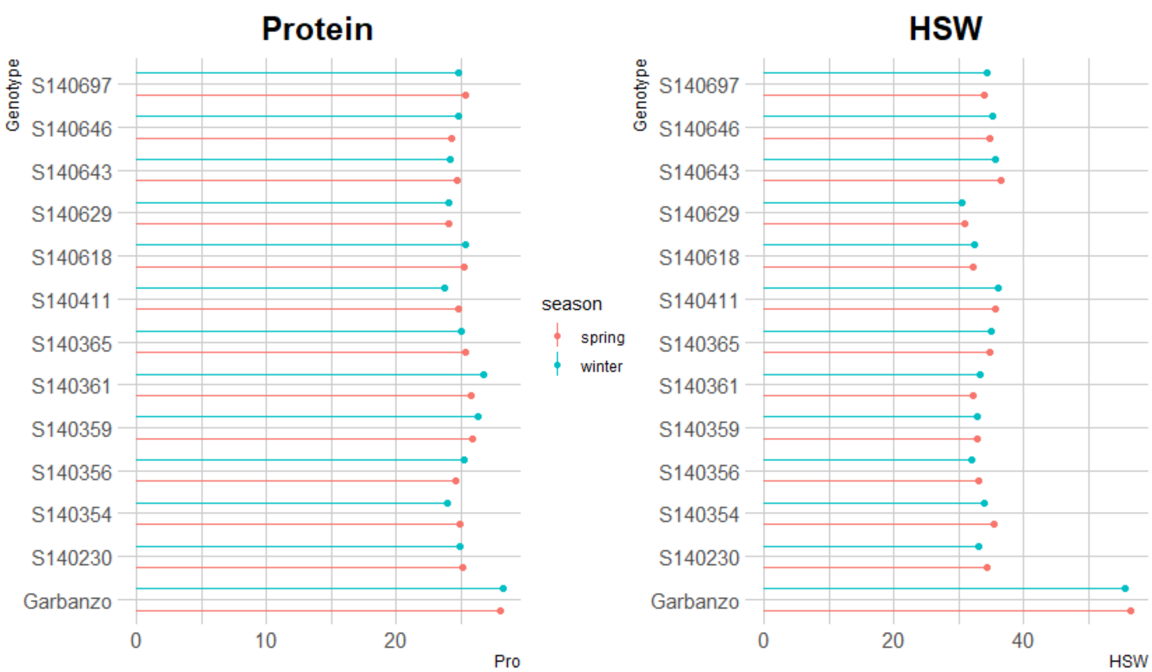
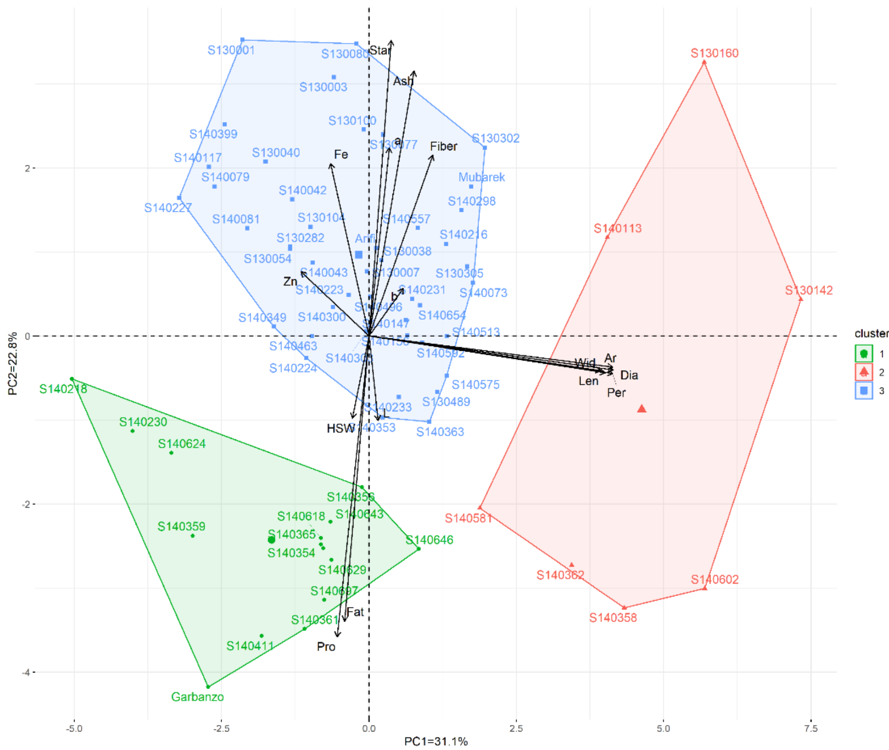


Figure 13. Protein and HSW values for green clustered genotypes of spring and winter planting

Spring



Winter

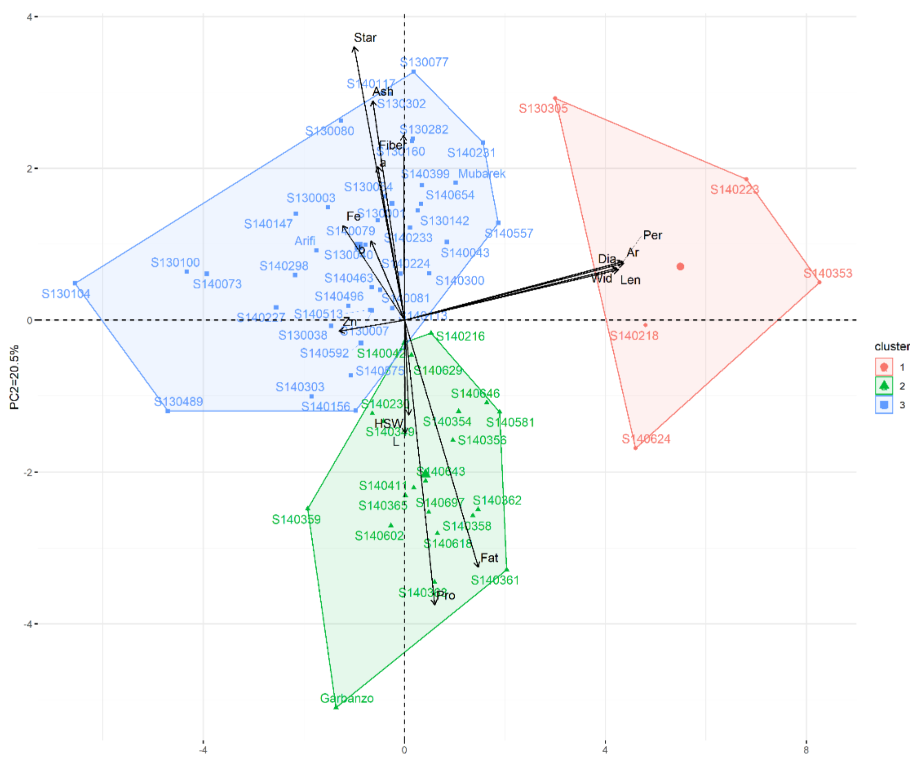


Figure 14. Principal components analysis of spring and winter planting

VI. Genotype selection

In order to compare and select superior genotypes for spring and winter planting, combined circular dendrograms with heatmap of many variables including protein, zinc, iron, HSW and grain yield were created (Fig.15). For both experiments dendrograms include two main groups, a group with most of genotypes having multiple medium to high values and the other with a majority of genotypes having low values for the majority of variables. Obviously in a comparative way, almost all winter genotypes have important yield. Interestingly, Garbanzo and genotype “S130003” were accounted for having the highest values of multiple traits in both experiments. Garbanzo has maximum values of protein, zinc and HSW with medium amount of iron and poor value of grain yield. On the other hand, the genotype “S130003” has great values of iron, HSW and grain yield while it has less protein and zinc. The genotype “S140147” has well performed only in winter for having great values of zinc, iron and grain yield.

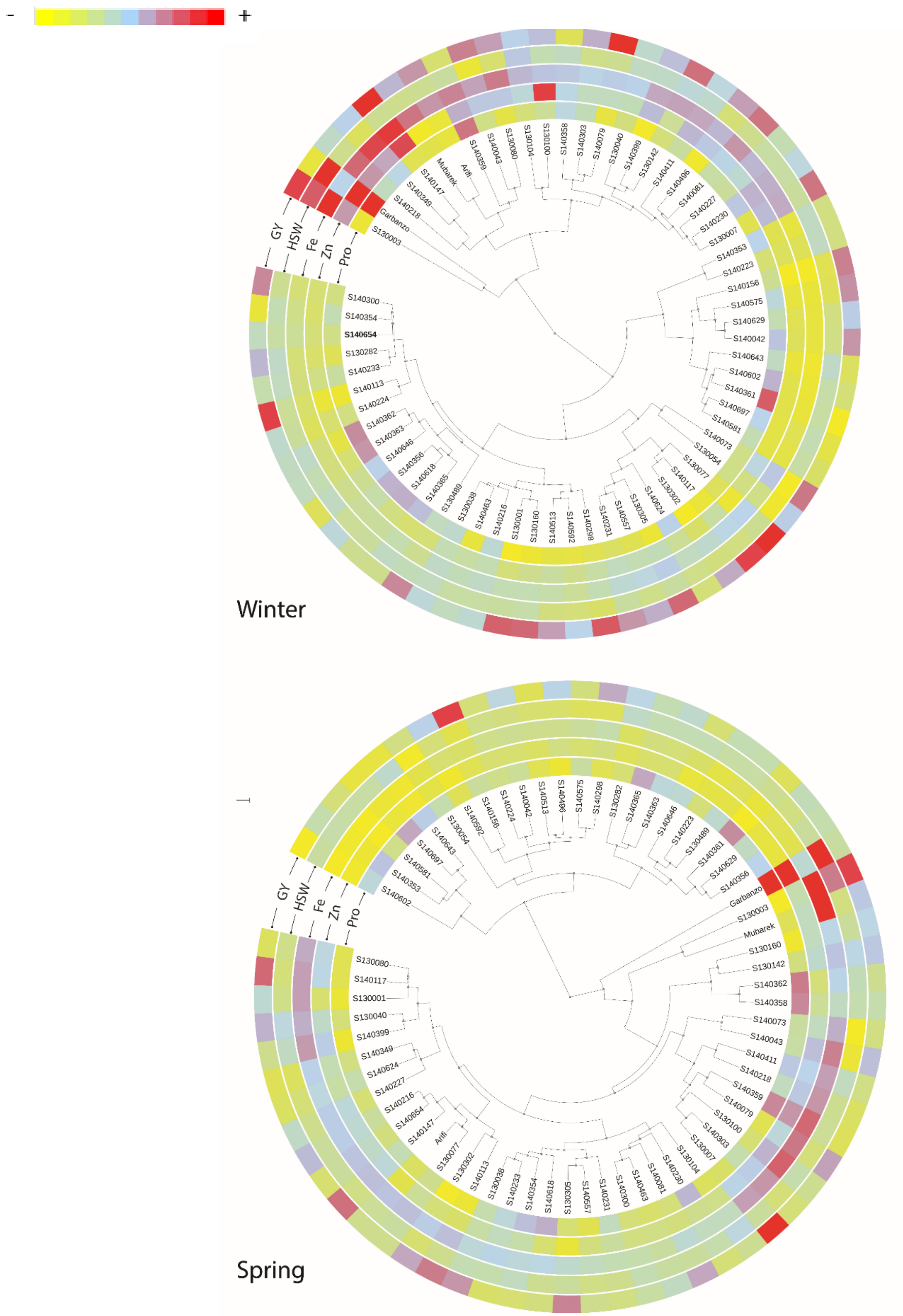


Figure 15. Combined circular dendrogram with heatmap of protein, zinc, HSW and yield under spring and winter planting.

VII. Weather impact on multiple traits for spring and winter planting

According to climate data summarized in figure 16, Temperature was low starting from below 10°C just after first sowing then it raised progressively till it reaches a maximum of 30°C in flowering stage of spring and post flowering stage of winter planting. Whereas it shows important precipitation between October and December of 2018 oppositely to 2019 months.

Table 11 below summarizes the coefficients of correlation between weather parameters (minimum temperature, maximum temperature, average temperature and rainfall) and each of HSW, protein, zinc and iron in addition to their significance. Result shows that HSW is affected negatively by rainfall during vegetative stage and minimum temperature during flowering stage for winter planting while it was strongly affected in a negative way by min and max temperature in vegetative stage and post flowering stage period respectively also by max and min temperature in vegetative stage and post flowering stage, respectively with a high significance, in addition to temperature, rainfall in vegetative stage has also a negative low correlation with HSW in spring planting. For winter planting protein is slightly affected in a positive way by rainfall in flowering stage but more influenced in spring planting by average temperature in post flowering stage. In term of mineral composition, zinc was positively affected by rainfall during post flowering stage in winter and average temperature in spring only flowering stage, whereas, adversely to iron which was negatively influenced during flowering stage in spring and vegetative stage in winter by min temperature and rainfall respectively.

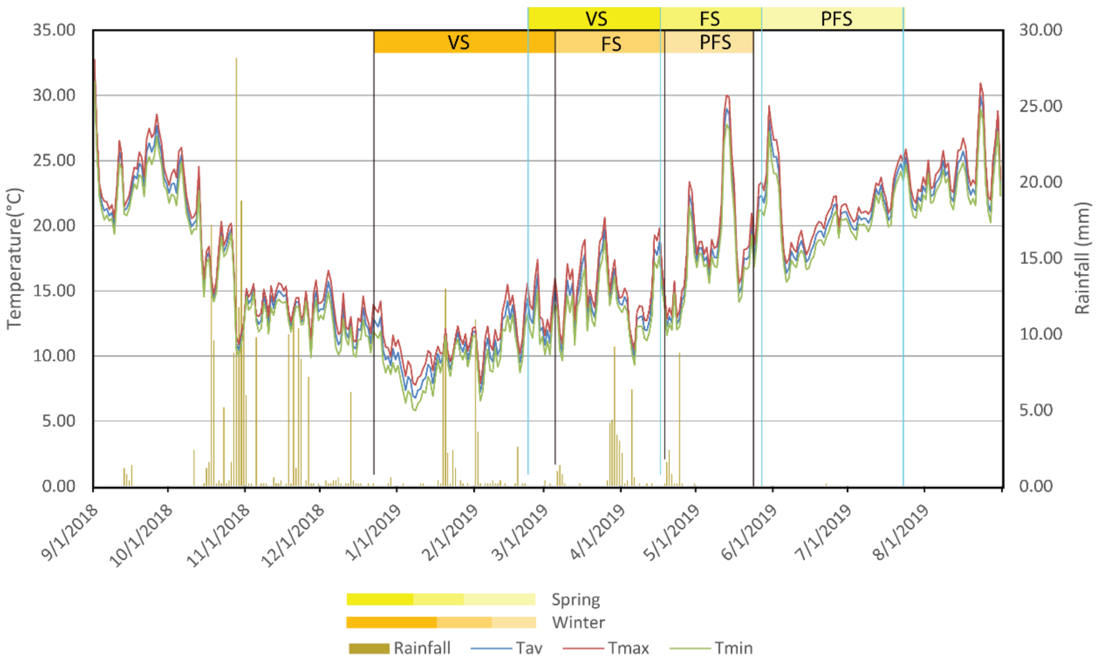


Figure 16.Variability of Tmin, Tmax, Tav and rainfall

Table 11. Coefficient of correlation between weather parameters and genotypes traits during different stages of plant development under spring and winter planting.

Discussion

In the last decade, food security and climate change became the first inquiry of many countries esspecially african countries. With the agricultural potential of Morocco, crop improvement represents one of key sources for food security assurance. AiPLaS team focuses on many crop legumes including chickpea for its potential in term of nutritional quality, thus the 66 selected genotypes for their resistance to some diseases and their good quality are making the subject of this project. We discovered important results and some interesting genotypes.

Results have shown no large difference in term of quality between winter and spring planting which could be due to lack of important precepitations mainly during post flowering stage of winter planting in addition to flowering stage and post flowering stage of spring planting (Fig.15), while the highest precepitation after winter planting was 13 mm and sum of precepitation along the period from november 2018 to august 2019 was only 183 mm, on the other hand, there was no conditions that could generate heat stress that usally occur in spring planting period, while temperature didn't surpass 30°C and for most of plant living period it was under 25°C, whereas, winter genotypes have been exposed to cold stress during vegetative stage. In addition to weather informations, gene-environment interaction show no important significant influence of sowing date on genotypes.

HSW didn't change largley among environment with a mean of 32.83 g in spring and 32.73 g in winter. It was the opposite in comparison with ozdemir and karadavut discover [29] who found an increase of 10% over spring sowing, moreover 'Sadeghipour and aghaei' have reported a range of 22.18 g to 27.12 g of HSW [30] while in our study HSW ranged from 28.36 g to 56.34 g in spring and 20.78 g to 55.53 g in winter. Highest HSW in 'Frimpong et al' study was 44.9 g [31], less than our values accounted for 56.34 g in spring and 55.53 g in winter. Winter protein range values were largley different from results of 'Sellami et al' [32] which was 21.37% - 28.23% against 19.2% - 21.70%.

In general, nutritional quality wasn't influenced by environment which is supported by regressions that showed strong correlations between similar traits among environments. In addition to heritability that was accounted for more than 0.8 for HSW, protein, fat, fiber, ash and iron also 0.63 and 0.76 for starch and zinc respectively. Similar results were found by 'Fermesk et al' concerning HSW and morphological traits [33]. Regarding morphological traits linear regression show no correlation between spring and winter and values distribution of winter was larger than spring's distribution and it's more notable by comparing significance of those traits.

In term of correlation, HSW was negativley correlated to starch and fiber and positivley to protein in a significant way which was the opposite for many studies like ‘Vandermark et al’ that reported minor to non significant correlation between HSW and carbohydrates [34] and as a principal component for production of cellulose, carbohydrates and proteins in chickpea according to Awatshi [35], sucrose was strongly correlated to seed size in Turner’s study [36], while Frimpong [31] have found a positive correlation between HSW and starch, adversely to findings of Sellami [32], whereas, Protein was negatively correlated with seed size according to Bandshah [37]. significant positive correlation between zinc and iron could be explained by zinc requirement for iron transfere from roots to shoots according to ‘A.Ullah’ [38].

First cluster in spring PCA graph and second one in winter are the most interesting groups of genotypes for being more related to HSW and protein. Moreover some of these genotypes have maintained their quality among spring and winter planting for belonging to the same cluster under spring and winter planting, more specifically, based on the circular dendrogram, selected elite genotypes were Garbanzo which has the highest amount of protein, zinc and HSW besides “S130003” with high amount of iron, HSW and grain yield, interestingly both genotypes have maintained these high values among environment changes. “S140147” is also an important genotype in winter planting for having high yield, zinc and iron though it has a weak performance in spring planting. Surprisengly Arifi and Mubarek variety belong to the same cluster level in winter with moderate iron content and yield, in contrast, under spring planting Arifi has less yield while Mubarek gained more iron content.

Conclusion

The nutritional quality assessment of chickpea seeds in response to winter and spring planting conditions revealed an important correlation between the seed size and some nutritional quality traits. The cultivar Garbanzo which is the mostly cultivated by farmers under spring planting showed high performances in term of seed size, protein content and Zn concentration against a low yield potential. The identification of high yielding lines such as '130003' characterized by high Fe concentration could be used in future breeding activities through specific crosses with Garbanzo. Garbanzo and '130003' didn't combine important minerals, protein content and yield at the same time but together they make a complement genotype we are looking for, thus, crossing between those two genotypes as a next step could bring out some interesting genotypes that assemble multiple important traits at least important yield and high amount of protein. More research is needed from a biochemical view in order to reveal the mechanisms behind correlation between some traits and genetic connection with nutritional traits and HSW. With magnitude increase of climate change disaster and diminished nutritional resources, Morocco has to orient its policy toward crop legume improvement mainly chickpea for being a good alternative as an accessible protein and mineral source that requires less energy and doesn't affect environment in a negative way like meat production does.

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