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Preliminary research on seed yield and nutritional traits of desi chickpea (*Cicer arietinum* L.) grown in Central Italy in spring sowing

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Abstract: In Italy, chickpea (*Cicer arietinum* L.) cultivation of the *kabuli* type is predominant, with local landraces of the *desi* type, including the Apulian black chickpea, occurring almost exclusively in the south. However, increasing interest in the *desi* type on the part of farmers and consumers is based on the nutritional properties constituting a niche area in the market health sector. Information pertaining to both field evaluation of *desi* chickpea in Central Italy and the chemical composition is scarce. Therefore, the aim of this preliminary research was to evaluate the agronomic performance to the agroclimatic environment of Central Italy of thirteen lines of *desi* chickpea accessions of different origins, as well as the 'Apulian Black Chickpea' (ABC). Accessions were sown on March 21 in 2019, without the use of irrigation. The principle qualitative characteristics, namely protein content and raw fiber were determined. Yield was excellent for 57 % of the accessions, some of which exceeded 3.0 t ha^{-1} with the maximum value of 4.1 t ha^{-1} recorded for 'PI598080' (brown seeds of Indian origin). 'W617611' (black seeds of Turkish origin) was the earliest flowering line at 74 days after sowing, permitting this accession to escape the onset of drought and high temperatures. Additional early flowering lines included 'PI533676' (black seeds of Ukrainian origin) and 'PI567850' (black seeds of Pakistani origin), respectively. Plant structure relating to the average height of the plants (47.0 cm), the height of the first pod (30.8 cm) and the number of branches per plant (2.6) rendered most accessions suitable to combine harvesting, an indispensable prerequisite in the maintenance of an economically sustainable crop. The average protein content was 22.7 % with maximum values exceeding 24 % ('PI572520' - black seeds of Syrian origin -, 'W617614' - black seeds of Turkish origin - and 'PI572850'). The fiber content was very heterogeneous ranging from 4.6 % to 12.0 %.The present study provides the basis towards the future introduction of *desi* chickpea in Central Italy, with the potential for sustainable yield and quality.

Key words: *Desi* chickpeas; Central Italy spring sowing; *Cicer arietinum* L.

Preliminarna raziskava o pridelku semena in hranilnih lastnosti čičerke (*Cicer arietinum* L.) tipa *desi*, rastoče v osrednji Italiji pri spomladanski setvi

Izvleček: V Italiji je pridelovanje čičerke (*Cicer arietinum* L.) izključno omejeno na južna območja, kjer gojijo pretežno *kabuli* tip, lokalno tudi domače lokalne rase tipa *desi* , vključno z apulijsko črno čičerko. Povečanje zanimanja za tip *desi* med kmeti in potrošniki temelji na njeni hranilni vrednosti, kar ustvarja nišo na trgu zdrave hrane. Podatki o vrednotenju pridelave in kemijski sestavi *desi* čičerke so v osrednji Itali zelo redki. Zaradi tega je bila izvedena preliminarna raziskava za ovrednotenje uspevanja v agroklimatkih razmerah srednje Italije na trinajstih linijah *desi* čičerke, z akcesijami različnega izvora, hkrati s črno apulijsko čičerko (ABC). Akcesije so bile posejane enaindvajsetega marca, leta 2019, brez namakanja. Določene so bile glavne kakovostne lastnosti, kot je vsebnost beljakovin in celokupnih vlaknin. Pridelek je bilo odličen pri 57 % akcesij, pri nekaterih je presegal 3,0 t ha^{-1}. Maksimalni pridelek, 4,1 t ha^{-1}, je bil zabeležen pri 'PI598080' (z rjavimi semeni, indijskega izvora). 'W617611' (s črnimi semeni, turškega izvora) je bila najzgodnejša v cvetenju, 74 dni po setvi, kar omogoča tej akcesiji, da pobegne suši in visokim temperaturam. Zgodaj cvetoče linije so vključevale še 'PI533676' (s črnimi semeni, ukrajinskega izvora) in 'PI567850' (s črnimi semeni, pakistanskega izvora). Zgradba rastlin, ki se nanaša na poprečno višino rastlin (47,0 cm), višino prvega stroka (30,8 cm) in število stranskih poganjkov na rastlino (2,6) je pokazala, da je večina akcesij primerna za žetev s kombajni, kar je nepogrešljiv predpogoj za ekonomsko vzdržno gojenje te poljščine. Poprečna vsebnost beljakovin je bila 22,7 %, z maksimalno vsebnostjo, ki presega 24 % ('PI572520', s črnimi semeni, sirijskega izvora, 'W617614', s črnimi semeni, turškega izvora in 'PI572850'). Vsebnost vlaknin je bila zelo različna in je znašala od 4,6 % do 12,0 %. Raziskava daje osnovo za bodoče uvajanje *desi* čičerke v osrednji Italiji, s potencialom vzdržnega pridelka in kakovosti.

Ključne besede: *desi* čičerka; osrednja Italija; spomladanska setev; *Cicer arietinum* L.

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1 INTRODUCTION

Chickpea (*Cicer arietinum* L.) is a widely used legume in the Mediterranean diet. After the Second World War, chickpea cultivation in Italy declined sharply, from 110,000 ha in 1950 to approximately 3,500 ha in 1999. However, based on the adoption of a more balanced diet, closer to that of the traditional Mediterranean diet, the importance of all legumes, including chickpea, were taken into consideration. This has been reflected in the increased cultivation, currently at 27,000 ha, of which production is predominantly directed towards the canned seed industry (Casini, 2018).

This notable increase was attributable, not only to the aforementioned food trends, but also to agronomic benefits such as reducing the use of both fertilizers and pesticides. In turn, this served to improve the structure and fertility of the soil and, above all, provide a more sustainable return to crop rotation with cereal crops (Palumbo, 2017; Watson et al., 2017). Together with the expansion of the areas dedicated to chickpea cultivation, yields have also increased. Yield increase is attributable to genetic improvement programs and innovative agronomic techniques, such as the use of symbiotic bacteria and selected mycorrhiza. Chickpea cultivation in Italy is composed predominantly of the *kabuli* type, characterized by large, clear and wrinkled seeds (Sarno and Stringi, 1980). Apart from some landraces, Italian varieties were derived mainly from genetic improvement studies conducted in the 1980s involving both Italian than foreign accessions. However, the availability of these varieties is very limited.

In southern Italy, chickpeas of the traditional type *desi* are widespread. *Desi* seeds are characterized by small, angular shapes of various colors, including either black, light brown or reddish seeds, with clear seeds being the most rare. Among these varieties, one of the most famous is the 'Cece Nero delle Murge' which, generically, is also referred to as 'Apulian Black Chickpea'. 'Le Murge' is a very large karst plateau, located between the regions of Apulia and northeastern Basilicata. In the north, red chickpeas, named 'Ceci Rossi di Orco Feligno' in Italian, also occur within small areas of the hinterland in the province of Savona in Liguria.

Consumers have become increasingly more attentive to quality, and are constantly looking for novel products that can ensure added value to the diet in the form of nutritional and/or nutraceutical properties. A good source of both protein and fiber is also one of the most sought-after characteristics. The chemical composition of *kabuli* and *desi* chickpeas differ significantly, especially in the raw fiber content, which is generally higher in the dark seeds (Rossi et al., 1984; Kaur and Singh, 2005; Costa et al., 2006; Ghosh et al., 2019). An additional important difference is in the oligosaccharide content, composed of raffinose, stachyose and verbascose, respectively. These oligosaccharides are responsible for impacts on flatulence, that is reported to be lower in *desi* seeds (Singh et al., 1982; Rossi et al., 1984). Bioactive compounds contained in the seeds also include carotenoids, anthocyanins, other phenolic compounds and phytate (Summo et al., 2019).

There are no statistics on the increase in the consumption of *desi* chickpeas in Italy. Generally, consumers in the market are attracted by their unusual attributes, as well as by differences in flavor compared to *kabuli*, despite the difficulties encountered in preparation (cooking), attributable to a high fiber content. In the past, this feature was a distinguishing characteristic of the *desi* chickpeas and for this reason black seeds were mainly destined for livestock feed. However, informal reports from organic product distributors and the appearance of canned *desi* chickpeas on the markets provided useful pointers on the merit of these seeds for human consumption. This coincided with the demand from farmers in both Central and Northern Italy for this type of chickpea. However, the availability of seed was limited to the few varieties that were cultivated exclusively in the area of origin, and preferably in organic farming, in order to maintain market value. In Italy, this type of chickpea, for which only landraces are available, is mostly characterized by modest yields. Moreover, the plant structure does not always facilitate mechanical harvesting and weed control. Reasons for this include the semi-prostrate structure of the plants, the tendency towards branching, and the positioning of pods closer to the ground.

There is very limited information on the field evaluation of *desi* chickpea in Italy (Casini, 1983) and, in particular, on the chemical composition (Rossi et al., 1984; Pavan et al., 2017; Summo et al., 2019).

The aim of this preliminary research was to evaluate the agronomic performance to the agroclimatic environment of Central Italy of thirteen lines of *desi* chickpea accessions of different origins, as well as the Apulian Black Chickpea (ABC).

To this end, sowing in spring was performed, and seeds produced were then analyzed for the principle qualitative characteristics in terms of protein content and raw fiber.

2 MATERIALS AND METHODS

The field experiment was carried out in Tuscany, Central Italy at the DemoFarm of 'Tenuta di Cesa-Terre Regionali Toscane (Province of Arezzo)', 43° 18' N; 11° 47' E; 242 m a.s.l. in 2019. The cultivation environment

Table 1: Origin and characteristics of the chickpea accessions

Accessions	Name	Origin	Seed color	Seed shape	Bearing
W611345	USSR-05-03-BD	Tajikistan	Black	Angular	Erect
PI533676	Sovhoznii 14	Ukraine	Black	Angular	Erect
PI598080	Desi chana	India	Brown	Angular	Erect
PI559361	Desi chana	India	Black	Angular	Erect
PI559362	Negro vicos	Spain	Brown	Smooth	Erect
W663498	ICC 4475	Syria	Black	Angular	Erect
PI572520	ICC 6328	Syria	Black	Angular	Erect
W617614	070689-0101	Turkey	Black	Angular	Erect
W617611	140689-0601	Turkey	Black	Angular	Erect
ABC	Apulian Black Chickpea	Italy	Black	Angular	Erect
PI572491	Porquero Negro	Mexico	Brown	Angular	Erect
PI567850	AOS 30	Pakistan	White	Smooth	Erect
PI518258	WKS 237E	Spain	Brown	Angular	Erect
PI518248	Myles	USA	Brown	Angular	Erect

was characterized by a neutral, loamy-sandy soil. The principle physical and chemical characteristics of the soil were as follows: sand 37 %, loam 39 %, and clay 24 %, respectively. The soil pH was 7.0. Total N was 0.11 % and P (Olsen) 13 ppm. Exchangeable Ca, Mg and K were 4123, 595 and 141 ppm, respectively. Meteorological data were recorded though SIAP automatic equipment, controlled and validated by the Regional Hydrological and Geological Sector. Thirteen accessions, provided by the North Central Regional Plant Introduction Station (Iowa State University, USA) and the Italian landrace 'Apulian Black Chickpea' (ABC) were used.

Based on previous experiments carried out in Central Italy (Casini, 1989), the Autumn-winter sowing period was not taken into consideration due to serious damage caused by anthracnose leaf blight. As a result, the sowing date selected was March 21, 2019. No symbiotic bacteria or mycorrhiza were utilized for seed inoculation; active root nodules were observed in all accessions. Plots were arranged according to a complete random block design, with three replicates. The size of the plots were 2.0 x 6.0 m (four rows wide with 0.5 m row spacing, respectively). The sampling area was comprised of two central rows, each of 4.0 m long, respectively. A seed quantity of 195 g per plot was used. In order to obtain the correct planting density of 35 plants m^{-2}, seedlings were thinned soon after complete emergence. Plots were hand-weeded twice (40 and 66 days after emergence [DAE]) during the growth cycle.

The agricultural interventions performed during the experiment are reported in Table 2.

Table 2: Agronomic techniques employed during the field trial

Previous crop	Wheat
Plowing	September 12, 2018
Harrowing	October 3, 2018
Harrowing	March 12, 2019
Pre-sowing fertilization	March 12, 2019
	N 52 kg ha^{-1} and P_2O_5 114 kg ha^{-1}
Sowing	March 21, 2019
Emergence	April 14, 2019
Harvesting	August 28, 2019

Plant height, stem number, height of the first pod (or ground clearance) and number of pods per plant were determined at the maturation stage, using a total of 10 plants per sample plot. Yield calculations and the 100 seed mass were performed using seed samples at a standard humidity of 12 %. Fifty percent flowering and maturity were estimated in the sampling plot areas.

Crude protein content of the seeds were performed in triplicate. The protein content was calculated by multiplying the nitrogen content by 6.25. The nitrogen content of 500 mg flour samples was determined by the FlashEA 1112 Series analyser (Thermo Fisher Scientific Inc., Waltham, MA, USA). Crude fiber content was determined according to the AOAC method (2006).

Data collected in the experiments were processed utilizing a one way randomized block analysis of vari-

Figure 1: Seed color and shape of chickpea accessions

ance (ANOVA). Differences between response variables were assessed with the COSTAT 6.45 software. Statistical differences were tested at $p \leq 0.05$, $p \leq 0.01$ or $p \leq 0.001$. The Tukey's HSD test was used to evidence significant differences between means and homogenous groups. The Pearson correlation coefficient (r) was calculated between all the quantitative variables.

3 RESULTS AND DISCUSSION

Figure 1 shows the climatic trends during the experiment. Average minimum and maximum temperatures were 9.7 and 24.6 °C, respectively. Rainfall was regular from immediately after emergence until fruit set (a total of 230 mm), thereby permitting optimal plant development. The subsequent phase, on the other hand, was characterized by a prolonged drought (50 days) and a maximum average temperature of 32 °C. The period of drought was then interrupted two weeks prior to harvesting, with over 200 mm distributed within 10 days with virtually no effect on seed filling.

The ANOVA reported in Table 3 evidenced significant differences at $p \leq 0.001$ for all the attributes examined.

Figure 3 shows the dates of the principle phenological phases (flowering, fruit set and maturity) for each of the accessions. 'W617611' was the earliest in flowering at 74 DAS whilst, ABC was the latest to flower at 90 DAS. As regards fruit set, 'PI533676' and 'PI598080' were the earliest and latest, respectively. The interval between the latter two phenological phases varied from 5 to 15 DAS for ABC and 'W617611', respectively. In Central Italy, the precocity of these phenological phases for chickpea sown in the spring, is of great importance. The capacity to flower earlier under the best conditions of soil moisture, permits maximum reproductive development prior to the onset of the dry period, which is also characterized by high temperatures. Drought periods represent one of the principle abiotic stresses responsible for the reduction in chickpea yield (Yücel, 2018). The occurrence of a short dry period during flowering, but also during fruit set and seed filling has been shown to reduce yield by 15-60 % (Yücel, 2019). These reductions have been shown to be dependent on both the geographical area and duration of the dry spell (Sabaghpour et al., 2006).

The climatic trend facilitated the development of all the respective reproductive phases of chickpea accessions under the best conditions. The lines with the best potential in escaping the first dry periods of the Central Italian cultivation environment were 'PI533676', 'W617611' and 'PI567850'.

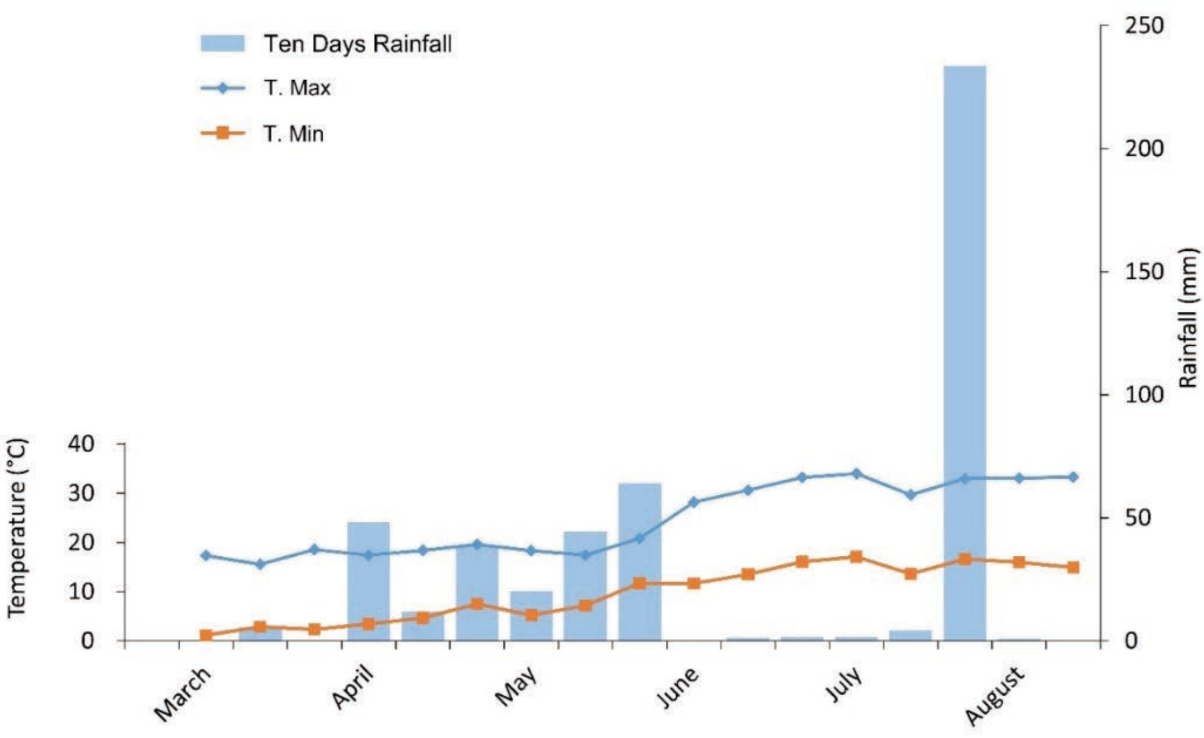

Figure 2: Temperature and rainfall recorded during the chickpea field experiment in 2019

Table 3: Analysis of variance

Source of variation	DF	Flowering	Fruit Set	Maturity	Plant Height	Height of First pod	Production strip	Stems per Plant	Filled Pods
Blocks	2	5.33	0.14	2.90	17.83	11.00	17.33	0.17	103.37
Accessions	13	1206.11***	413.14***	423.16***	2752.29***	893.99***	734.31**	10.79***	5613.61***
Error	26	40.66	39.85	11.76	610.34	176.23	453.78	3.78	417.75
Total	41	1252.11	453.14	437.83	3380.47	1081.22	1205.43	14.74	6134.73

Source of variation	DF	Empty Pods	Seeds per Plant	Seeds per Pod	Seed Mass per plant	100 Seeds Mass	Yield	Protein	Crude Fiber
Blocks	2	1.14	129.13	0.10	1.04	40.67	0.84	0.02	0.03
Accessions	13	66.37***	17473.28***	4.95***	633.38***	2197.96***	33.97***	112.44**	184.52***
Error	26	7.46	501.22	3.16	4.36	158.92	5.60	3.94	0.11
Total	41	74.97	18103.64	8.22	638.78	2397.56	40.42	116.4	184.66

, *: significant at $p \leq 0.01$ and $p \leq 0.001$ respectively

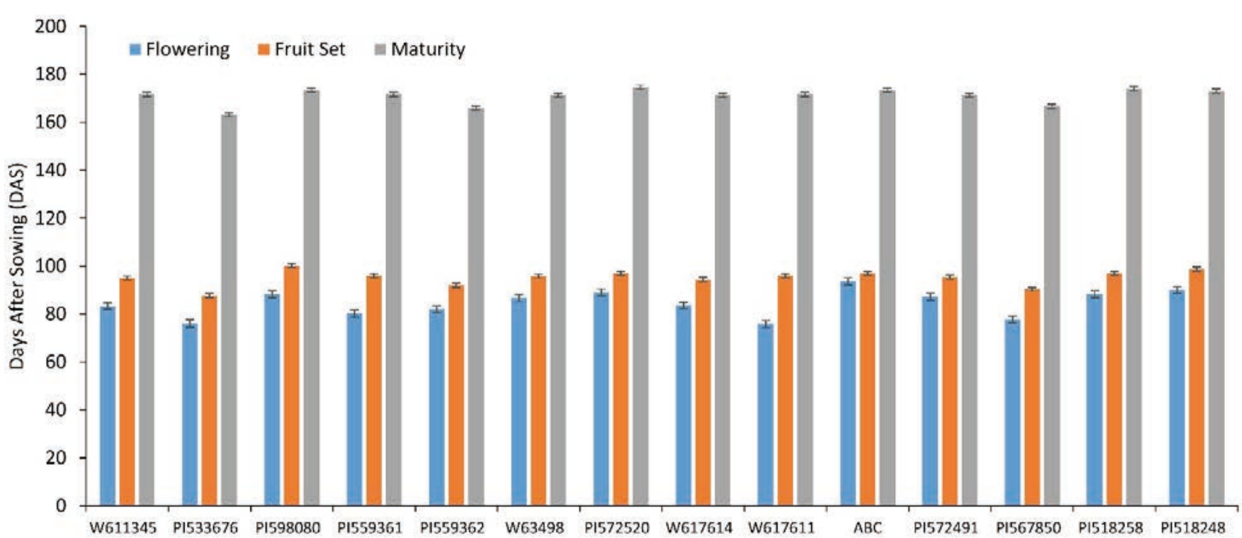

Figure 3: Dates of the principle phenological phases of the accessions. Error bars represent the interval of the variability of the Tukey test. If the bars do not overlap, the difference between averages is significant at $p \leq 0.05$

Ripening ended between 160 DAS ('PI533676') and 175 DAS ('PI598080'). Although late ripening, may lead to better seed production, it can lead to problems from an agronomic point of view, especially as regards soil preparation (ploughing) for subsequent cultivations. In Central Italy, it is common to sow an autumn-winter cereal (mainly wheat) after chickpea. With predominantly clay type soils, early soil preparation is essential in order to permit atmospheric agents to effectively disintegrate the clay clumps prior to sowing the cereal crop (late October-November). Even a two-week difference in the ploughing date can make a significant difference. Hence, in this context, early ripening chickpea accessions are preferable. On the other hand, the depth of the chickpea roots and the physic-chemical state of the soil after harvesting may result in the application of less heavy processing techniques than ploughing using, for example, minimum tillage or the two-layer ploughing.

Table 4 shows the quantitative characteristics. Plant structure, plant height, as well as the height of the first pod above ground level, are important traits determining the suitability of the accessions for combine harvesting. In this experiment, the height of the plants varied from 34.1 cm to 59.3 cm reported for 'PI559361' and

'PI567850', respectively. Instead, the height of the first pod from the ground varied from 22.6 cm to 40.5 cm for 'PI559361' and 'PI572520', respectively. Pod height and plant height are positively correlated (r = 0.009**) depending on genotype, corroborating previous research (Singh et al., 2019).

To ensure effective combine harvesters, ground clearance must be more than 30 cm (Chaturvedi et al., 2014; Vishnu et al., 2020). The present results showed that, besides the aforementioned accession, 'PI572520", with the maximum above-ground pod height, that additional eight accessions, with an average height of 34.7 cm (W611345, PI533676, PI598080, PI559362, ABC, PI572491, PI567850 and PI518248) met this require-

Table 4: Results of the quantitative characteristics and morphological traits

Accessions	Plant Height (cm)	Height of first Pod (cm)	Production Strip (cm)	Stems per Plant (n)	Filled Pods per Plant (n)
W611345	45.2 a-e	31.3 bcd	13.9 ab	2.1 bc	15.5 ef
PI533676	53.1 abc	31.3 ab	21.8 ab	3.3 a	43.6 ab
PI598080	49.1 a-d	30.7 bcd	18.3 ab	2.5 abc	23.3 cde
PI559361	34.1 e	22.6 e	11.4 ab	1.5 c	11.2 f
PI559362	50.4 abc	34.3 abc	16.0 ab	2.5 abc	12.3 ef
W63498	38.8 cde	25.7 de	13.0 ab	3.1 ab	52.1 a
PI572520	59.3 a	40.5 a	18.8 ab	3.3 a	24.1 cde
W617614	39.6 cde	27.0 cde	12.6 ab	2.2 abc	17.1 def
W617611	40.4 b-e	28.8 cde	11.6 ab	2.9 ab	21.2 def
ABC	54.9 ab	31.9 bcd	22.9 a	2.7 ab	34.6 bc
PI572491	53.2 abc	33.8 abc	19.3 ab	2.3 abc	22.6 c-f
PI567850	58.6 a	36.8 ab	21.7 ab	2.9 ab	26.0 cd
PI518258	35.2 de	25.1 de	10.0 b	2.2 abc	18.2 def
PI518248	45.5 a-e	31.8 bcd	13.6 ab	3.2 ab	13.2 ef
Mean	47.0	30.8	16.1	2.6	23.9

Accessions	Empty Pods per Plant (n)	Seeds per Plant (n)	Seeds per Pod (n)	Seed Mass per Plant (g)	100 Seeds Mass (g)
W611345	2.4 bc	20.5 de	1.3 ab	3.79 ef	18.7 bc
PI533676	3.2 ab	54.7 b	1.2 ab	12.4 a	22.4 b
PI598080	0.6 d	23.2 cde	1.7 ab	3.8 e-g	17.1 cd
PI559361	0.3 d	14.4 e	1.2 b	1.5 h	11.0 de
PI559362	1.3 cd	25.0 cde	2.0 a	5.8 bc	23.6 b
W63498	2.4 bc	87.2 a	1.6 ab	12.9 a	13.8 cde
PI572520	2.5 bc	34.5 c	1.4 ab	8.3 bc	23.7 b
W617614	1.8 bcd	14.0 e	0.8 b	2.8 de	20.7 bc
W617611	2.5 bc	25.2 cde	1.1 ab	4.4 ef	16.7 cd
ABC	4.6 a	62.7 b	1.8 ab	8.5 c	14.1 cde
PI572491	4.8 a	33.3 cd	1.5 ab	3.7 ef	10.8 de
PI567850	2.7 bc	30.9 cd	1.2 ab	9.8 b	31.0 a
PI518258	1.57 cd	30.3 cd	1.7 ab	4.4 bc	17.2 e
PI518248	1.43 cd	12.0 e	0.9 b	3.8 e	32.6 a
Mean	2.3	33.4	1.4	6.2	19.5

Means within rows followed by the same letter(s) are not different at 5% level as per Tukey's test ment. Mechanical harvesting is advantageous in reducing production costs, even if seed losses must be taken into account in relation to plant structure. According to Haddad et al. (1988), the use genotypes producing tall, erect-structured plants, seed losses ranged from 2.6 to 5.0 % compared to losses of 20 % in semi-erect plants.

In this experiment the concept of "production strip" was introduced. This terminology refers to the productive part of the plant spanning the distance between the height of the first pod to the top of the plant, that can serve as a useful indicator in the regulation of combine harvesters. The production strip was positively and significantly related to plant height (r = 0.018*), height of the first pod (r = 0.001**), the number of empty pods (r^2 = 0.017*), the mass of the seeds per plant (r = 0.002**) and the protein content (r = 0.046*).

The number of branches per plant was also related to plant height and the height of the first pod (r = 0.031* and r = 0.022*, respectively). Table 4 shows an average branching number value of 2.3.

The structure of chickpea plants has been shown to be partly modified by sowing density. Singh et al. (2019) reported, with reference to the prerequisite of genotype for mechanical collection, how both the height of the plants and that of the first pod can be increased by increasing plant density. However, the response to a large number of plants per m^2 varies according to genotype and the agro-climatic environment.

The number of pods per plant, divided between full and empty, is an indication of the fruit set capacity and production potential. In the present experiment, the average number of pods per plant was 23.9, with a maximum of 52.1 and a minimum of 11.2 recorded for 'W63498' and 'PI559361', respectively. The lowest number of empty pods was shown by the accessions 'PI598080' and 'PI559362' with values of 0.6 and 0.3, respectively, corresponding to 2.6 and 2.7 % of the total pods. The accession with the highest number of empty pods was 'PI572491', accounting for 21.2 % of the total number of pods. However, the data must be evaluated against the number of seeds produced per plant and the number of seeds contained in a pod. As regards the number of seeds per plant, the average value was 38.4. The highest number of seeds per pod was reported for 'W63498' (87.2) and 'ABC' (62.7), respectively, which were significantly higher than the remaining accessions but also significantly different from each other. The number of seeds per plant was positively and significantly correlated with the number of branches per plant (r = 0.009**) and that of both full (r = 0.008**) and empty pods (r = 0.009**).

The accession with the highest number of seeds per pod was 'PI559362' (2.0), and this genotype was followed by the accessions, ABC (1.8), 'PI598080' and 'PI518258' (1.7), respectively. The genotypes that showed a significant minimum number of seeds per pod compared to remaining accessions, were W617614 and PI518248 with values of 0.8 and 0.9, respectively. The mean number of seeds per pod in the present field experiment (1.4) corroborated previous work, reported by Mohibullah et al. (2020).

Seed production per plant, as expressed by mass, is a quantitative character that is closely related to almost all other parameters with the exception of flowering period, height of the first pod and number of seeds per pod (Table 5). The average value was 6.2 g $plant^{-1}$ with the maximum values above 10 g recorded for 'W63498' (12.9) and 'PI598080' (12.4), respectively. Significantly lower seed mass were recorded for group composed of 'PI567850' (9.8), ABC (8.5) and 'PI572520' (8.3), respectively.

The 100 seed mass provides an indication of the size of the seeds which, in the present study, was averaged at 19.5 g. This figure appears to be lower than that observed previously with regard to the *desi* type of chickpea (Ton and Anlarsal, 2017; Mohibullah et al., 2020). The values were similarly lower compared to previous field tests, on other accessions, in the same geographical area (Casini, 1983). This could be attributed to varietal characteristics and to a reduced adaptation to the agroclimatic environment, as well as to the drought period that characterized much of the seed filling phase. However, values above 30 g per 100 seeds were obtained from 'PI518248' (32.6) and 'PI567850' (31.0). Moreover, other accessions, including PI572520 (23.7), PI559362 (23.6), PI533676 (22.4) and W617614 (20.7) recorded values similar to those found in the previously cited literature. According to Ton and Anlarsal (2017), the 100 seed mass has a high degree of heritability and is an important varietal feature to be taken into account in genetic improvement programs for the international scientific community.

The average seed yield was excellent, attaining 3.0 t ha^{-1} despite the aforementioned drought period thanks to the good distribution of rains from April to the first decade of June. The most productive accessions were PI559362 (4.8), PI598080 (4.1) and the group W63498, PI572520 and ABC with an average of 3.7 t ha^{-1}, respectively. The accession with the lowest yield was PI518248 with 1.1 t ha^{-1}.

The average protein content of 22.7 % was considered excellent, with maximum values exceeding 24% for 'PI572520', 'W617614' and 'PI572850'. These values were shown to be higher than those reported previously (average of 18.5 %) for *desi* type chickpeas cultivated in the same environment (Rossi et al., 1983; Casini, 1983). The protein values were similarly higher than those reported in recent studies conducted outside Italy (Ghribi et al., 2015; Serrano et al., 2017; Rybiński et al., 2019). Contra-

Table 5: Pearson coefficient of correlation (r) for traits of investigated accessions

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Flowering	-															
2	Fruit Set	.008**	-														
3	Maturity	.009**	.008**	-													
4	Plant Height	.575	.052	.096	-												
5	Height of First Pod	.518	.343	.357	.009**	-											
6	Production Strip	.745	.018*	.056	.008**	.001**	-										
7	Stems per Plant	.857	.366	.411	.031*	.022*	.155	-									
8	Filled Pods	.948	.112	.118	.324	.001**	.110	.003**	-								
9	Empty Pods	.303	.199	.787	.003**	.022*	.017*	.073	.003**	-							
10	Seeds per Plant	.262	.245	.530	.327	.941	.073	.009**	.008**	.009**	-						
11	Seeds per Pod	.169	.632	.862	.491	.011*	.330	.777	.832	.180	.003**	-					
12	Seed Weight per Plant	.529	.002**	.015*	.004**	.894	.002**	.001**	.008**	.004**	.001**	.117	-				
13	100 Seed Weight	.320	.093	.095	.003**	.849	.100	.005**	.587	.616	.281	.358	.057	-			
14	Yield	.712	.887	.958	.296	.448	.304	.871	.166	.733	.016*	.009*	.057	.713	-		
15	Protein	.624	.114	.150	.045*	.074	.046*	.943	.252	.169	.513	.889	.286	.746	.043	-	
16	Crude Fiber	.911	.259	.218	.006**	.001**	.314	.852	.095	.160	.341	.046*	.810	.153	.439	.154	-

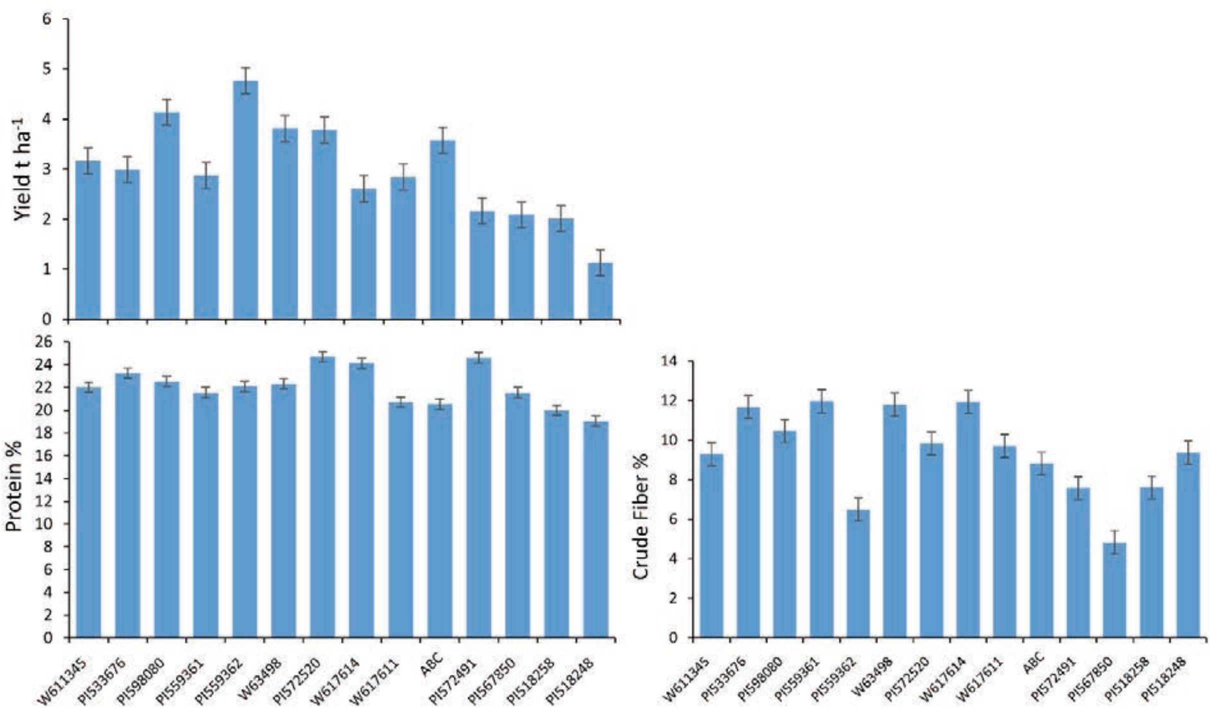

Figure 4: Yield, protein and crude fiber content of the accessions tested. Error bars represent the interval of the variability of the Tukey test. If the bars do not overlap, the difference between averages is significant at $p \leq 0.05$

ry to the observations of Kulwal and Mhase (2017), no significant positive correlation between seed mass and protein content was found. Instead there was a significant correlation between protein content and both plant height (r = 0.045*) and production strip (r = 0.046*).

The fiber content was very heterogeneous (Figure 3). A group of four genotypes were shown to have values above 11.0 %, with a maximum of 12.0 % for 'PI559361'. Another group of five lines was characterized by values between 8.0 and 10.0% (W611345, PI572520, W617611, ABC, PI518248). The lowest value of 4.8 % was shown for 'PI567850', characterized by clear tegument. The high fiber content, while characterizing various groups of chickpeas from a qualitative point of view, also denotes a prolonged mean cooking time, generally exceeding 120 min. This is also associated with low hydration capacity (≥ 0.16 g), as attested by Khan et al. (1995).

4 CONCLUSIONS

In view of the scarce experimental information on the possibility of cultivating *desi* chickpea genotypes in Central Italy, outside the cultivation area of Southern Italy, the present results permitted us to make some interesting observations.

Grain yield was considered of an excellent level for 57 % of the accessions tested, some of which exceeded 3.0 t ha^{-1}, with the maximum value of 4.1 recorded by 'PI598080'. This yield capacity was perfectly comparable to that obtained on the same experimental farm in 2016 and 2017 using *kabuli* chickpea accessions, selected for the production of canned seeds (Casini, 2018). In practice, the present results show that by selecting the most adaptable genotypes for the agroclimatic environment, even the cultivation of *desi* chickpea can be cost-effective for farmers, whilst demonstrating all the well-known agronomic benefits characteristic to legumes. The market share in Italy currently occupied by the *desi* chickpeas is a niche area limited to the health sector. In part, this serves to attenuate the highly unstable chickpea market prices, attributable to the high yield variability and competition from cereal crops, such as rice and wheat, considered as commodities, that also receive a price support policy by governments (Merga and Haji, 2019).

Taking into account the type of Italian market for which the production of *desi* chickpea is intended, the excellent average protein and dietary fiber content are able to meet the needs of the consumer, thereby placing this type of seed in the category of foods considered complementary to the Mediterranean diet. These products, especially if produced in organic farming, have an added market value, resulting in a higher retail price that the consumer is generally willing to support after acquiring knowledge of the beneficial characteristics. In Italy, from a commercial point of view, the size of chickpea seed is an important factor influencing consumer preference. Taste in size has been based on the prevalent spread of *kabuli* chickpea (mass of 100 seeds > 45-50 g). This preference has also been "transferred" to the *desi* chickpea, and for this reason, genotypes allocated to the Italian market, will need to favor larger seed accessions with a 100 seed mass exceeding at least 30 g. From this point of view, only two tested genotypes satisfy this requisite, namely 'PI518248' (brown seed) and 'PI567850' (black seed).

Most of the accessions, in addition to possessing a good yield, also possess a plant structure, suitable for mechanical harvesting. The height of the first above-ground pod exceeding 30 cm, with fewer branches and an average production strip of 16.1 cm, are all characteristics that correspond to an ideotype of chickpea in which production is concentrated at the top of the plant, thereby facilitating all cultivation operations, from weeding, to hilling, to harvesting. From this point of view, the genotypes that conform perfectly to the ideotype, and with good yields, were PI598080, PI559362, PI572520 and ABC.

With regard to the ABC, the only accession of Italian origin, the grain yield was of an excellent level, even when cultivated in the environment of Central Italy. However, as reported by Summo et al., (2017), this genotype is characterized by a significantly lower protein content than all other accessions. The same authors also pointed out that the chemical, nutritional and functional characteristics of ABC, are generally distinctive from both *kabuli* chickpeas and foreign-sourced *desi* chickpeas.

Finally, the overall indications emerging from the present research provide the basis towards laying the foundations for the future introduction of *desi* chickpea in Central Italy, with the potential for sustainable yield and quality.

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