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D1.1 Adaptability of different crops in Europe

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Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	X
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 635727.

1. Introduction and Objectives

Today in EU there is a large dependency on animal proteins (meat) for human consumption. Despite their high value, many protein crops have not been adequately assessed and numerous species are underutilized. Special attention has to be paid to genetic diversity and landraces. Increasing the proportion of vegetable proteins and decreasing those of animal origin in the human diet is the main objective of the project PROTEIN2FOOD. To achieve this, main sources of plant proteins we need to screen different protein crops based on seed yield, quantity and quality of proteins, and anti-nutrient levels.

This report will explain the preliminary test carried out to evaluate the adaptability of different proteins crop in three different climatic regions of Europe (Denmark, Netherland and Italy). In particular, preliminary tests were conducted in open fields using different genotypes of grain legumes, and pseudocereals that are candidates to satisfy the growing demand for plant protein production worldwide. Specific objectives for this deliverable are related to;

- Adaptability of different crops in Europe
- Identification of the adaptability of different crops and cultivars in three climatic regions of Europe.

2. Activities for solving the tasks

Field trials were performed to identify the adaptability of different crops. A screening of species, cultivars and accessions of high *protein quality crops* and *high protein level crops* with potential to be produced in Denmark, Italy and Netherlands was performed in 2015-2016.

In Denmark simultaneously, a sowing date trial with one accession per crop species was performed to study crop adaptation: In Italy and Netherlands different sowing density were evaluated

2.1. Denmark

2.1.1. Environmental conditions

The screening and sowing date trials were conducted at the experimental station in Taastrup (Højbakkegaard), University of Copenhagen, 25 km west of Copenhagen. Geographically it is located at 55°40′N latitude, 12°18′E longitude and an altitude of 28 m above sea level. The study site is characterized by a sandy loam soil.

Denmark is located at the edge of the European continent; it has a typical coastal climate relatively warm for its latitude. Mean annual temperature is 7–9 °C and annual precipitation 640–770 mm (Cappelen, et al., 2016). In general, for the 2015 growing season (April to October), Taastrup showed a moderately warmer and dryer weather compared to the country averages as it can be observed in Table 1.

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Table 1. Monthly temperature and precipitation observed in Taastrup and in Denmark during the 2015 growing season

Month	Mean temperature (°C)			Accumulated precipitation[1] (mm)		
	Taastrup[2] 2015	Denmark[3] 2015	Denmark[3] 2001 – 2010	**Taastrup[1,2] 2015**	Denmark[3] 2015	Denmark[3] 2001 - 2010
April	9.1	7.0	7.5	20.7	27	37
May	12.2	9.7	11.4	75.3	86	53
June	19.7	12.7	14.6	51.9	59	68
July	25.1	15.5	17.4	24.8	86	77
Aug	20.6	17.4	17.2	125.0	69	91
Sept	18.4	13.2	13.8	70.6	94	62
Oct	13.7	9.5	9.4	136.0	29	83

[1] Precipitation is measured at 1.5 m above ground level
[2] Data from meteorological station located in the research site
[3] Mean temperatures and accumulated precipitation for Denmark (2015 and average 2001 – 2010) are obtained from 7 stations covering the country (Cappelen, et al., 2016).

2.1.2. Genetic material and experimental design

Table 2. Species and accessions cultivated for screening in 2015 and 2016

Trial name		**Screening**	
Year		**2015**	**2016**
Growing season		**April - October**	
N°	**Species**	**Number of accessions**	
1	Quinoa (*Chenopodium quinoa*)	7	7
2	Amaranth (*Amaranthus* spp.)	6	6
3	Buckwheat (*Fagopyrum esculentum*)	12	18
4	Lentil (*Lens culinaris*)	10	10
5	Chickpea (*Cicer arietinum*)	5	5
6	Faba bean (*Vicia faba*)	4	5
7	Pea (*Pisum sativum*)	10	10
8	Lupin (*Lupinus* spp.)	4	4
9	Soybean (Glycine max)	-	7

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Screening 2015 – 2016

Figure 1 Aerial photography from screening

In Denmark the screening of selected species was performed in one location with 58 accessions from 8 species in 2015, and 72 accessions from 9 species in 2016 (Table 2).

Crops were grouped and arranged randomly, considering crop and pest management aspects (e.g. legumes were grouped together in order to protect them with electric fences).

One accession was included per species in the screening with 8 species in 2015 and 9 in 2016. Sowing dates are spaced by 15 days.

Sowing date 2015 – 2016

Figure 2 Aerial photography from three-sowing date trial with three replications (first replication of first sowing date is found in screening trial).

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Winter faba beans

Figure 3 Test of six Faba bean accessions (June 2016).
Left: spring sowing, right: winter sowing.

For Faba bean six accessions were sown under a randomized block design and three replications.

2.2. Italy

2.2.1. High protein quality crops

The experiment was carried out at the experimental research station of CNR-ISAFoM located in the lower Volturno river basin (41°12’ N and 14°20’ E, 23 m above the sea level), Vitulazio (Caserta). The soil of the trial site is characterized by a clay-loam texture and the climate is Mediterranean sub-humid with annual average values of rainfall of about 805 mm and annual reference evapotranspiration (ET0 estimated by Penman–Monteith equation) of about 1157 mm in the period 1976–2014.

The experimental farm, where the field experiments are performed, is equipped with a new automatic agro-meteorological station (iMetos ag, mod. IMT 280, Pessl Instruments, AT).

Measurements of air temperature and humidity, wind speed and direction, global solar radiation and rainfall, are performed every 5 minutes, and their average is stored every 60 minutes. Moreover, the software calculated the reference evapotranspiration according to Allen et al. (1998). Data are available in real time on the web to the people responsible for the weather station; data are also stored daily on a server at ISAFOM and made available to the researchers and technicians involved in the project.

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Figure 4 Quinoa and Amaranth experimental plots in Vitulazio (CE)

A randomized complete block split-split plot design with three replicates was applied. Ten quinoa and amaranth genotypes (Table 3) were randomly assigned to the main plots; sowing densities were assigned to the split-plot. Also two theoretical sowing density were evaluated of respectively 200000 and 100000 plants per hectare with 0.5-m row spacing. All genotypes were sown at the end of April and will be evaluated under rainfed conditions. In 2015, sowing took place on 16 April. Preliminary preparations were made before sowing, beginning in October 2014 with weed removal. After 20 days, subsoiling was done in order to break up the soil and allow drainage and aeration even in the deeper layers. In both years of trials, before sowing in the spring, soil tillage was done twice and a strategy for fertilizer application was defined. This involved 60 kg ha^{-1} of nitrogen (N) that was applied in pre-sowing, and also in the same quantity after emergency at four leaves. Nitrogen was supplied in the form of ammonium nitrate (NH_4 NO_3) at 34%.

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Table 3. Quinoa and amaranth genotypes evaluated in Italy

Species	Genotype	Provider nationality	Type
Quinoa	Titicaca	Denmark	Variety
Quinoa	Puno	Denmark	Variety
Quinoa	Vikinga	Denmark	Variety
Quinoa	Regalona Baer	Chile	Variety
Quinoa	Riobamba	Italy	Accessions
Quinoa	Red Carina	Italy	Variety
Quinoa	Red head	Italy	Variety
Amaranth	A5	Denmark	Accession
Amaranth	A7	Denmark	Accession
Amaranth	A14	Denmark	Accession

2.2.2. High protein level crops

Two field trials were carried out in two different locations: the first at the experimental research station of **ISAFoM** located in the lower Volturno river basin (41°12' N and 14°20' E, 23 m above the sea level). The soil of the trial site is characterized by a clay-loam texture and the climate is Mediterranean sub-humid with annual average values of rainfall of about 805 mm and annual reference evapotranspiration (ET0 estimated by Penman–Monteith equation) of about 1157 mm, in the period 1976–2015. The second filed trial was carried out at the experimental research station of **ISAFoM** in Assoro-Enna (Sicily region) (290 m.a.s.l.), characterized by clay- loam soil.

For the screening trial, a randomized complete block design with three replicates was applied. Eight lentil, chickpea and grass pea genotypes (Table 4) were randomly assigned to the plots in Assoro and five genotypes in Vitulazio. The theoretical sowing density applied were evaluated of respectively 200 (lentil), 100 (Grass pea) and 40 (Chickpea) plants per square meter with 0.25-m row spacing. All genotypes (Figure 5) were sown in the first days of November in Vitualzio and middle January in Assoro. The sowing date in Assoro was delayed due to the seasonal high air temperature and absence of rainfall until the end of 2015. Both trials were conducted under rainfed conditions.

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Table 4. Legumes compared in the screening trial

Species	Genotype	Origin	Type	Exp Station
Lentil	Itaca	Italy	variety	Assoro/Vitulazio
Lentil	Nera di Enna	Italy	accession	Assoro
Lentil	Caltagirone	Italy	accesion	Assoro
Lentil	Aidone	Italy	accession	Assoro
Grass pea	Marchigiana	Italy	accession	Assoro/Vitulazio
Chickpea	Sultano	Italy	variety	Assoro/Vitulazio
Chickpea	Reale	Italy	variety	Assoro/Vitulazio
Chickpea	Pascià	Italy	variety	Assoro/Vitulazio

Figure 5 Legumes experimental plots in Vitulazio (CE)

Figure 6 Legumes experimental plots in Assoro (EN*)*

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2.3. Netherland

Emergence crop development on both sandy locations in the eastern parts of The Netherlands (Holten and Klazienaveen) have been made for the faba beans, white and blue lupins. Almost all plots have been harvested and are being dried, weighed and cleaned. The trials on the clay locations with white lupin and quinoa (Haarlemmermeer and Swifterbant) were assessed for the same traits and have been harvested, cleaned and dried.

Mean yields were determined and lsd's. After a very cold and wet spring season, the weather turned to high temperatures and drought. Especially in Holten this drought caused a lot of the varieties to ripen too early due to shortness of water. In Klazienaveen the soil moisture situation was less limiting in the summer period due to higher ground water tables and more rainfall.

Almost all plots were harvested with a trial harvester in two periods (mid-August and beginning of September). At the clayey trial sites all white lupins and quinoa plots were harvested by hand.

3. Results

3.1. Denmark

This section contains the results from the screening and the sowing date trial in 2015. The screening 2016 and winter faba bean trials are still in development.

Screening 2015

The screening showed variable yields for all crops (Table 5).

Table 5. Screening trial (April – October 2015) with 58 accessions of 8 protein crops

N°	Species	Acc[1]	Range of yield (kg ha^{-1})	Observations
1	Quinoa (*Chenopodium quinoa*)	7	48 – 869	Local material had better yields
2	Amaranth (*Amaranthus* spp.)	6	85 – 1723	83% of accessions yield <1 t ha^{-1}
3	Buckwheat (*Fagopyrum esculentum*)	12	7 – 284	Low yields
4	Lentil (*Lens culinaris*)	10	292 – 1954	60% of accessions yield < 1 t ha^{-1}
5	Chickpea (*Cicer arietinum*)	5	1 – 335	Low yields
6	Faba bean (*Vicia faba*)	4	1630 – 1953	Uniform high yields
7	Pea (*Pisum sativum*)	10	309 – 2722	50% of accessions yield > 2 t ha^{-1}
8	Lupin (*Lupinus* spp.)	4	0 – 1303	Losses and damages by hares

[1] **Acc**: Accessions

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Sowing date 2015

Quinoa and amaranth showed no differences in yield ($p>0.05$), even after one month sowing date difference (Figures 7 and 8).

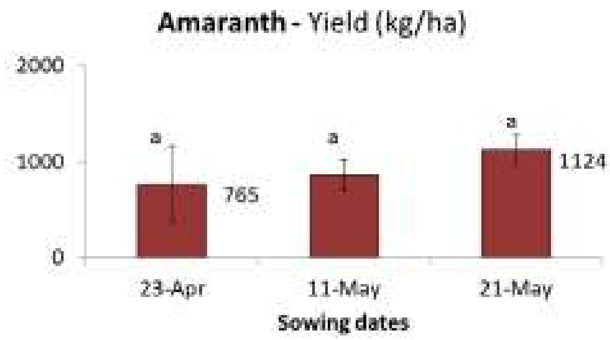

Figure 7 Yields of Amaranth (*Amaranthus spp*) sown in three different sowing dates

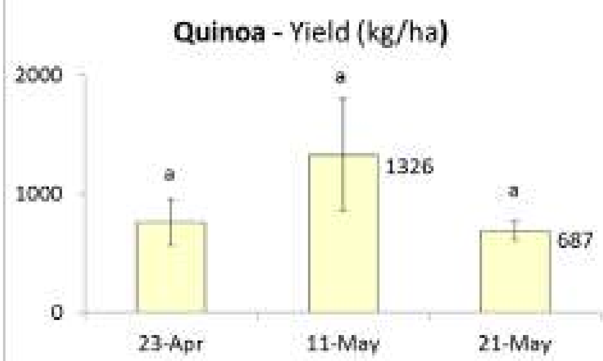

Figure 8 Yields of Quinoa (*Chenopodium qunoa,* **Willd.) sown in three different sowing dates**

Buckwheat showed significantly ($p<0.05$) better yields at later sowing date (21 May) (Figure 9).

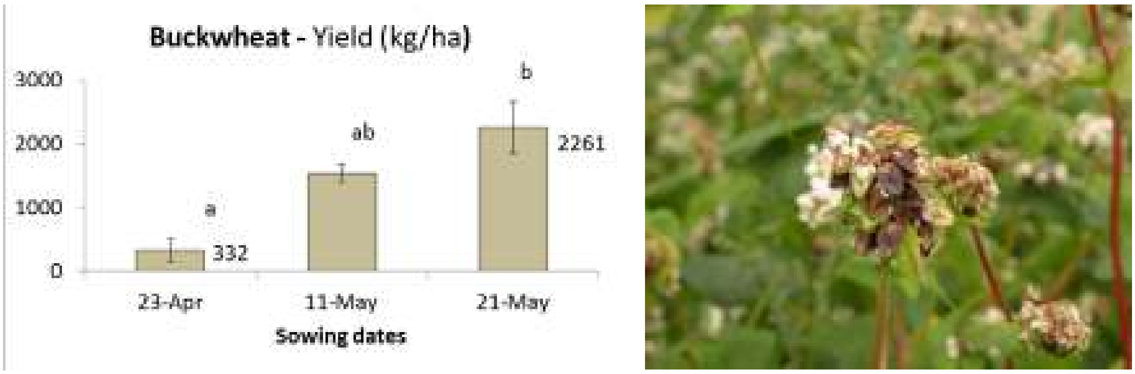

Figure 9 **Yields of Buckwheat (*Fagopyrum esculentum*) plants sown in three sowing dates in Denmark**

Legumes (faba bean, pea, lentil, chickpea and lupin) had highest yields ($p<0.05$) under early sowing (Figure 10). These species were more susceptible to pests (hares, weeds and birds) during the 2015 growing season.

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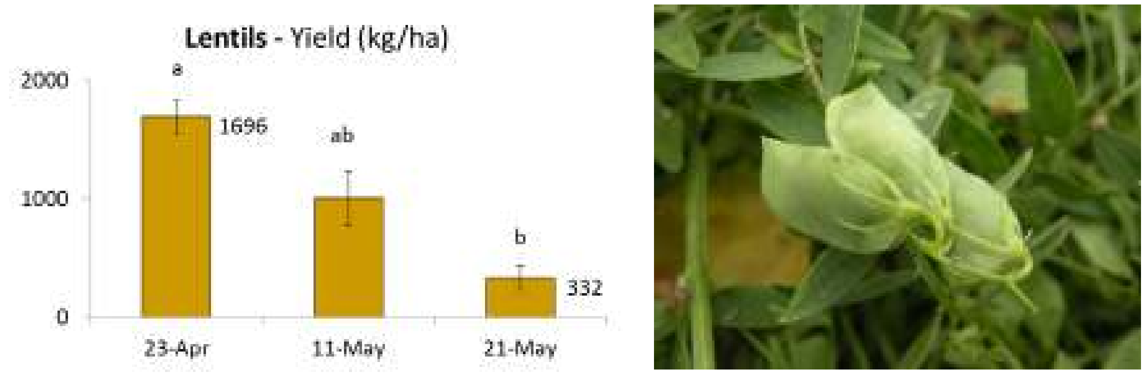

Figure 10 Yields from Lentil (*Lens culinaris*) plants sown in three sowing dates in Denmark

3.2.Italy

3.2.1. High protein quality crops

The analysis of main climatic parameters during the field trials (April-August 2015), showed that the 2015 growing season was characterized by warmer and rainy conditions than the long-term 39 years: mean air temperature was 1.89 °C higher and the rainfall was 10% greater (199 mm), as compared with the long-term 39 years (181 mm). The rainfall distribution during the growing season greatly affected the behavior and the response of crop to water deficit.

Sowing of different quinoa and amaranth genotypes took place on 16 and 17 April 2015 and the harvest took place on 5 August 2015 for quinoa varieties Titicaca, Vikinga, Puno and Regalona and from 6 to 12 August 2015 for quinoa varieties Red Carina, Riobamba and Amaranth accessions 5, 7, and 14.

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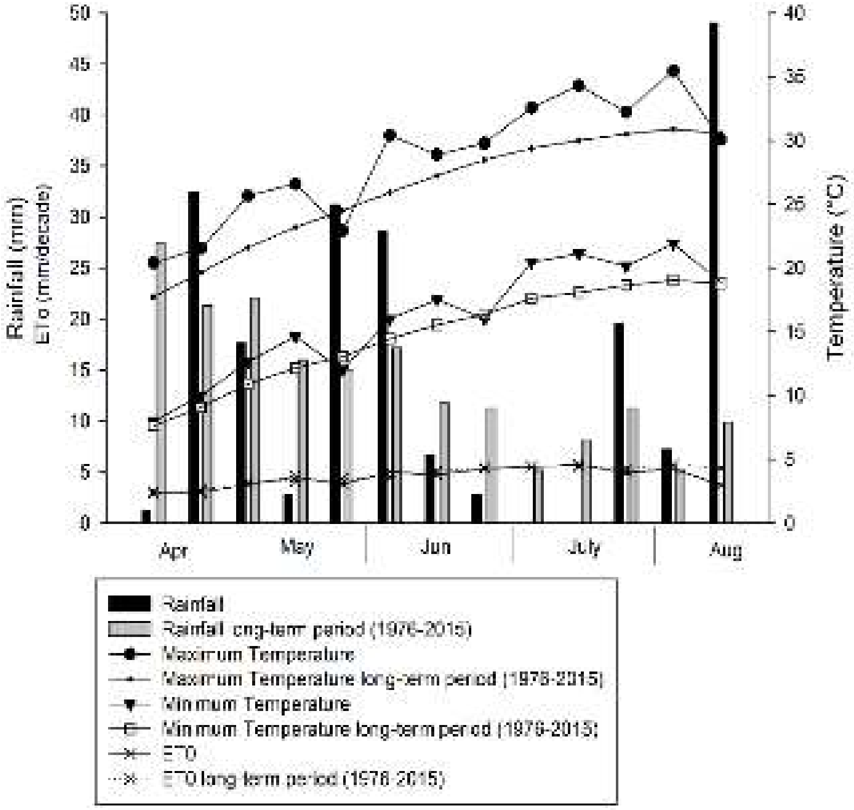

Figure 11 Main weather conditions in Vitulazio from April to August 2015

Table 6 and 7 report the analysis of variance results for the main examined variables (Genotypes and Density) of Quinoa. Overall dry above biomass and emersion were significantly affected by genotypes and desnsity.

The seeds yield, plant height and plant diameter were not significant affected by sowing density (Table 6 and 7), but they varied significantly in relation to genotypes; the highest seeds yield was recorded in Titicaca (0.8 t.ha-1, Figure12, Table 6), this variety showed also the highest rate of emersion in the field. The lowest value of seeds yield was recorded in CARINA with 0.09 t.ha-1. Quinoa Riobamba showed the highest value in terms of biomass, plant height and plant diameter (Table 6).

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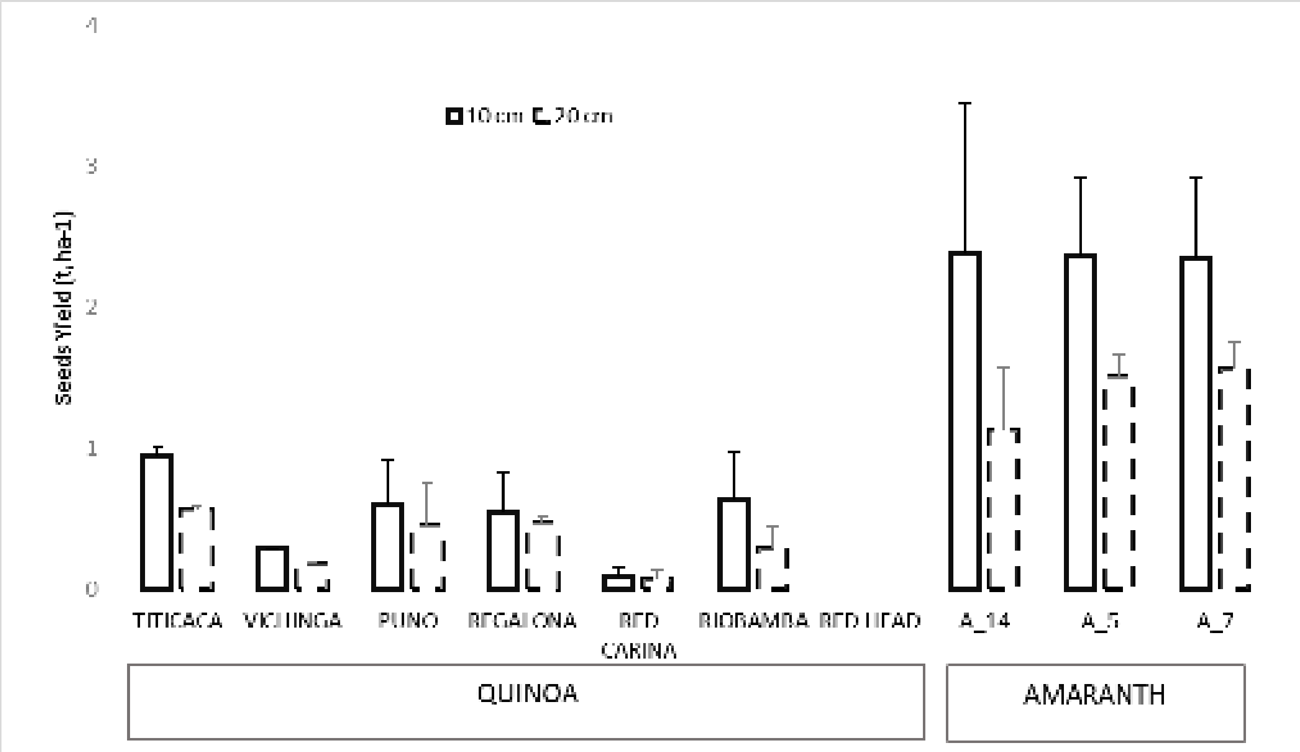

Figure 12 Quinoa and Amaranth seeds yield, Values are represented as mean ± SE.

Table 6. Yield parameters and emersion of quinoa results

Source of variation	**Dry Biomass** *(t. ha^{-1})*	**Seeds Yield** *(t. ha^{-1})*	**Emersion** *(%)*
Genotype (C)	**	**	***
TITICACA	2.11 c	0.76 a	67 a
VIKINGA	1.44 c	0.24 bc	62 a
PUNO	1.76 c	0.53 ab	63.5 a
REGALONA	3.23 bc	0.51ab	32.25 b
CARINA	6.43 ab	0.09 c	30 b
RIOBAMBA	7.26 a	0.46 ab	27.75 b
Density (D)	**	NS	***
10 cm	5.18 a	0.52	56.58 a
20 cm	2.23 b	0.34	37.58 b
C x D	NS	NS	**

***, *** indicate respectively differences at P≤0.01 and P≤0.001; ns indicates not significant difference.*
Means followed by the same letter in each column are not significantly different according to the LSD test (P≤0.05).

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Table 7. quinoa biometric parameters results

Source of variation	Height *(cm)*	Diameter *(cm)*
Genotype (C)	**	*
TITICACA	82.58 a	6.67 b
VIKINGA	59.17 b	6.42 b
PUNO	83.75 a	7.17 b
REGALONA	88.54 a	9.67 a
RIOBAMBA	91.42 a	9.17 a
Density (D)	NS	NS
10 cm	78.82	7.30
20 cm	83.37	8.10
C x D	NS	NS

**, ** indicate respectively differences at $P \leq 0.05$ and $P \leq 0.01$; ns indicates not significant difference.*
Means followed by the same letter in each column are not significantly different according to the LSD test ($P \leq 0.05$).

Table 8 and 9 report the analysis of variance results for the main examined variables (Accessions and Density) of Amaranth. Overall yield response, dry above biomass and emersion were not significantly affected by genotypes. Above ground biomass and seeds yield were significantly affected by sowing density (Table 8). Sowing density of 10 cm gave higher biomass (28.92 t. ha^{-1}) and greater total yield (2.36 t. ha^{-1}).

Table 8. Yield parameters and emersion of Amaranth results

Source of variation	Dry Biomass *(t ha^{-1})*	Seeds Yield *(t ha^{-1})*	Emersion *(%)*
Accessions (C)	NS	NS	NS
5	21.10	1.93	67.75
7	20.90	1.96	62.5
14	26.62	1.75	67.25
Density (D)	**	*	NS
10 cm	28.92 a	2.36 a	80.5
20 cm	16.83 b	1.40 b	51.17
C x D	NS	NS	NS

**, ** indicate respectively differences at $P \leq 0.05$ and $P \leq 0.01$; ns indicates not significant difference.*
Means followed by the same letter in each column are not significantly different according to the LSD test ($P \leq 0.05$).

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Table 9. Amaranth biometric parameters results

Source of variation	Height *(cm)*	Diameter *(cm)*
Cultivars (C)	NS	NS
5	124.42	17.83
7	133.33	17.50
14	136.67	17.33
Density (D)	NS	NS
10 cm	131.83	16.56
20 cm	130.44	18.56
C x D	NS	NS

ns indicates not significant difference. Means followed by the same letter in each column are not significantly different according to the LSD test (P≤0.05).

3.2.2. High protein level crops

In Vitulazio (CE) the climatic trend was different from the polyannual (1976-2015) reference trend, especially in the case of volume and distribution of rainfall. In Figure 13, the monthly mean temperature, the rainfall and the reference evapotranspiration for Leguminous growing season (2015-2016), compared with long-term values (1976-2015). The rainfall during October to June was higher in 2015-2016 (841.8 mm) than the long-term 39-year average of 750 mm.

Over the Leguminous growing season (2015-2016) the average mean temperature (19.6°C) was higher than the long-term average (17.4°C).

Moreover, the total of reference evapotranspiration was slightly lower in 2015-2016 by 11.32% compared to 39-year period.

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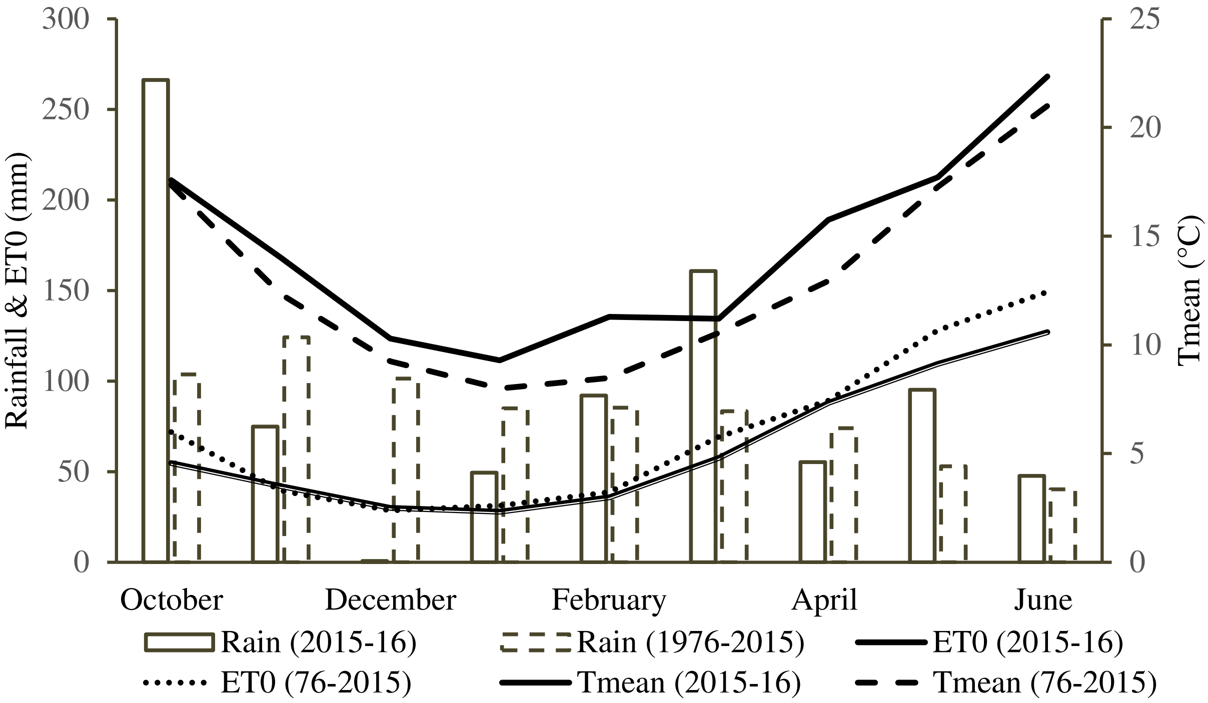

Figure 13 Monthly rainfall, reference evapotranspiration (ET0) and average air temperature (Tmean) at the study site (Vitulazio) for Leguminous growing season (2015-2016), compared with long-term values (1976-2015).

In Vitulazio, the highest seeds yield productions were recorded for chickpea (Table 10); in particular, the varieties Reale and Pascià showed significate higher yields respect the chickpea Sultano. Seeds yield of grass pea and Lentil were similar to those reported in literature.

Table 10. Legumes yield and biomass in Vitulazio (CE)

Specie	Variety	Total biomass *t ha⁻¹*		Seeds yield *t ha⁻¹*	
		**		**	
Cickpea	Reale	6.49	a	4.12	a
	Sultano	3.08	a	1.98	b
	Pascià	4.93	a	3.24	a
Grass pea	Marchigiana	2.72		1.02	
Lentil	Itaca	3.78		1.34	

** indicate respectively differences at $P \leq 0.01$; ns indicates not significant difference.
Means followed by the same letter in each column are not significantly different according to the LSD test ($P \leq 0.05$).

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In Assoro from sowing to harvest date only 104 mm of rainfall were recorded (data not shown). Seeds yield value recorded in Assoro (Table 11) for chickpea var. Reale and Pascià were lower respect to those recorded in Vitulazio On the other hand grass pea seed yield in Assoro was higher respect those reported in Vitulazio. The Lentil ecotypes Caltagitone, Aidone and Nera di Enna showed higher seeds yield respect the registered variety Itaca.

Table 11. Legumes yield in Assoro (EN)

Specie	**Variety**	**Seeds yield** *t ha^{-1}*
Cickpea	Reale	1.67
	Sultano	1.58
	Pascia	1.81
Grass pea	Marchigiana	2.78
Lentil	ITACA	1.10
	Caltagirone	1.52
	Aidone	1.98
	Nera Enna	1.94

3.3.Netherland

For blue and white lupins and faba beans yields have been determined on two sandy locations. Faba beans were only grown organically and what was apparent that the adjustability of Faba beans to aphids and chocolate spot disease is still quite poor.

For that reason, yields have been quite low (2.5-2.8 t ha^{-1}) compared to yields in good years (4-5 t ha^{-1}). This coincides with the farmer experiences that especially organically grown faba beans can vary in yield quite a lot due to susceptibility to aphids and chocolate spots. Susceptibility to disease was also seen for white lupine. Fungal pressure was quite high on the moist sandy location, causing a considerable decrease in yield of the branching variety Amiga. The blue lupine had an average year with lower yields on the dry sandy location due to early drought in June.

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Figure 14 Lupin sowing density trial

Table 12. Seeds yield in Netherland

		Sand		Clay
		Moist	**Dry**	
	Variety		t ha^{-1}	
Spring wheat		6.20	3.33	
Faba beans	Imposa	2.51		
	Gloria	2.48		
	Bioro	2.68		
	Fuego	2.79		
White lupin	NB Boros	1.99	2.15	
	BR Amiga	1.88	3.20	
Blue lupin	NB Primadonna	2.80	2.80	
	Haags Blaue	2.62	1.87	
	SB Boruta	3.02	2.17	
	Regent	3.22	2.56	
	BR Iris	3.02	2.54	
	Boregine	2.66	2.12	
	Probor	2.98	1.85	
	Mirabor	2.52	1.97	
Quinoa	Titicaca			2.97
	Puno			2.55

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Table 13. Sowing density trial results in Netherland

	Primadonna			Iris		
	pl/m²	*t ha⁻¹*	%	*pl/m²*	*t ha⁻¹*	%
60%	84	2.76	-2%	51	2.86	-5%
80%	93	2.84	1%	73	2.92	-3%
100%	123	2.80	0%	79	3.02	0%
120%	151	2.74	-2%	112	3.15	4%

In the sowing density trials with blue lupins no significant yield effect was seen for either the non-branching variety Primadonna or the branching variety Iris. Even with plant densities as low as 60% of the normal plant density yields only seemed to be moderately (non-significantly) decreased.

Table 14. Breeding lines tested in Netherlands

		Sand Moist (*t ha⁻¹*)	Sand Dry (*t ha⁻¹*)	Lodging Resistence	Earliness
Non-branch.	Primadonna	2.80	2.80	10.0	7.7
	Regent	3.22	2.56	9.0	8.0
	SZS NB1	2.27	2.03	10.0	8.2
	SZS NB2	1.85	1.79	9.3	8.3
	SZS NB3	1.78	2.18	10.0	8.3
Branching	Iris	3.02	2.54	6.8	5.3
	SZS BR1	2.97	1.85	6.0	3.8
	SZS BR2	3.26	2.28	9.7	3.5
	SZS BR3	2.68	1.80	1.7	4.5
	SZS BR4	2.92	2.41	6.7	3.3
	SZS BR5	2.75	2.11	7.7	3.8
	SZS BR6	1.84	2.36	3.0	3.5
	SZS BR7	3.26	1.95	6.0	4.3
	SZS BR8	2.50	1.77	5.8	4.0

For breeding and selection a cooperation was formed between the main breeding company of blue lupins in Europe: Saatzucht Steinach. 11 breeding lines were tested and scored under Dutch growing conditions. A large part of these lines seemed to be not that well-adjusted to the Dutch climatic and agronomic conditions. The non-branching varieties all had a very small crop height and poor weed suppression capabilities. The branching varieties all were quite late in ripening and some having a poor resistance to lodging.

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4. Conclusions

Each partner will continue screening within P2F project with the best material using the best lines and varieties that showed highest adaptability to specific environments. In addition, starting from second year, common varieties quinoa, fava bean and lupin will be tested in different locations using a common experimental protocol. Genotype per environment per management analysis will be carried out using 2 sowing date. 3 environments. and 7 crops (3 quinoa genotypes Titicaca. Puno. Vikinga. 4 lupin genotypes: Iris, Primadonna, Regent, Borghine). The screening studies will be conducted also on morphological and qualitative traits of seeds; X-ray CT scans and 3D image analysis of seed and relationship between pericarp thickness and protein content will be shared between CNR and SLU.

5. Delays and difficulties

In Denmark the major problem was the presence of pests. Hares (*Lepus europaeus*) affected the development of legumes such as lupin and chickpea in the first year (2015). To reduce losses. nets and electric fences were installed. Weeds also affect the development of crops. therefore they are controlled at initial growth stages both with mechanical and hand weeding (Figures 15 and 16).

Figure 15 Hand weeding (July 2015)

Figure 16 Mechanical hoeing in buckwheat (June 2016)

In Netherland some problems have occurred with the emergence in 2015. The white lupin breeding lines were preselected for sweetness but had to be treated quite fiercely due to hard shellness and this fierce treatment has reduced the emergence capabilities of most lines. This resulted in very poor emergence for most white lupin breeding lines. making a good yield assessment impossible. For the faba beans another problem arose as on one of the locations (Holten) a very fierce night frost (-10 °C) occurred during emergence and caused more than 90% of the emerging plants to die. On the other location the faba beans emerged very well.

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In Klazienaveen fungal development limited the production more than drought. For the faba beans chocolate spot disease (*Botrytis cinerea*) occurred in a relative early stage of development. causing most varieties to ripen too early. For the lupins a combination of Brown leaf spot (*Pleiocheata setosa)*. *Sclerotinia* and *Fusarium* as primary infections and *Alternaria* as a secondary infection caused some varieties to die off earlier than intended.

In Italy only some problems in the early vegetative stage of quinoa and amaranth due to leaf defoliators (Altica *spp.*) insect attack were recorded; anyway this not affected the final seeds yield.

6. Any potential for dissemination activities

Research activities in the Protein 2 Food project have been disseminated in the MSc course Tropical Crop Production at the University of Copenhagen. The importance of the studied species as protein sources was emphasized to 40 students from 23 different countries, and the trials were used as teaching tools (Figure 17).

Nine students interested in the project requested their participation in the project to learn and develop research skills (Figure 18).

Figure 17 Sowing date trial used during a practical with MSc students from UCPH (August 2015)

Figure 18 Jenny Dueck. Canadian student developing extra activities in the project with quinoa (March 2016)

Seeds of 5 species and 12 accessions from the screening trial of 2015 were requested by a Danish stakeholder (Årstiderne) interested in growing the material in their farm. Årstiderne produces organic vegetables that are delivered directly to their customers. Crops are successfully implemented and under development in the present growing season (2016).

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Seeds from quinoa, amaranth and faba bean have been tested in the menu of a Danish restaurant "Mad Mad Mad Bodega".

Figure 19 Mad Mad Mad Bodega's chef trying new recipes

Figure 20 Restaurant website with "Meatfree Menu" offer

The rolling Danish – Peruvian restaurant "Panca" tested the Danish quinoa cultivar "Vikinga" in one of their dishes (quinoa salad) during a health event in Copenhagen (Figures 19 and 20). There was high demand and interest of consumers as well as from the owners of the restaurant who expressed interest to acquire the local quinoa in the future.

Figure 21 Panca restaurant menu with quinoa salad announcement (May 2016)

Figure 22 Quinoa salad with Danish quinoa cultivar "Vikinga" (May 2016)

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International students from the University of Copenhagen are compiling a recipe-book to promote the consumption of Amaranth with a goal of 50 creative recipes. Friends and colleagues participated as sensorial panels in 10 events giving feedback on taste and texture (Figures 21 and 22). Dishes such as burgers, pancakes, pudding, diverse soups, salads, beverages and desserts based on Amaranth and mixed with different ingredients from the international cuisine are creatively composed with positive success among tasters.

Figure 23 Snacks prepared with four products harvested from screening trials (March 2016)

Figure 24 Students preparing an amaranth tasting with the participation of a sensor panel of 14 persons. In the picture students involved in the activity (from left to right: Sumitra Paudel, Arnesta Odone, Laxmi Lama and Natalie Hoidal - June 2016).

The outcome of the data from trials in Netherland have been presented at the annual meeting of the consortium meeting in Poland in February and some of the data will be published in an magazine for organic agriculture (Ekoland). Seeds from 2015 have been shared with WP2 (Frauenhofer Institute) for protein isolation. For the white lupin breeding program, the seeds from different accessions have been selected for sweetness. For the blue lupin cooperative breeding results are shared with the breeding company (Saatzucht Steinach) and selection has been made for the new accessions that will be tested in the coming year.

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