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Spectral phenotyping of bread and durum wheat grown in North and South Italy in response to N and S fertilization strategies for yield, quality and sustainability

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Introduction
The achievement of higher sustanibility, both in terms of higher resource use efficiency and of lower GHGs emissions, is a challenging goal of the EU 'Farm to Fork Strategy', which aims to reduce the fertilizers use by 20% (Cortigiani et al., 2022). On the other hand, the lower inputs should not contrast with the demanding requirements of food in terms of quantity and quality. In order to achieve these goals it is suggested that the the smart agriculture approach, with the use of low-emissions fertilizers and digital farming, could help to optimize agronomic management for crops (Raimondi et al., 2021). Non-destructive spectral phenotyping of crop physiological status and, in particular, the variability of crop N demand is a key aspect to achieve sustainable goals. To this aim, the response of four bread and durum wheat genotypes to different N fertilization strategies, including N rate, S supply, timing and co-application of nitrification inhibitors, was assessed by crop spectral phenotyping, under two Mediterranean environments of North and South Italy, characterized by marked climatic differences.

Materials and Methods
The field experiments were conducted during two crop seasons 2019-20 and 2020-21 in North Italy at Carmagnola (44°50' N, 7°40' E; 245 m s.l.m.) and in South Italy at Foggia (CREA CI, 41°27′03" N, 15°30′06" E; 70 m s.l.m.), called respectively TO and FG. The two environments are characterized by differences in annual mean temperature (11.6 °C at TO, 16.7 °C at FG) and rainfall amount (765 mm at TO, 565 mm at FG). At TO, soil was classified as silty loam with 2.25% of organic matter, 0.163% of total nitrogen (Dumas), 14 ppm of available phosphorous (Olsen method) and pH 8.1; on the other hand, soil at FG was loam with 2.39% of organic matter, 0.193% of total nitrogen (Dumas), 36.5 ppm of available phosphorous (Olsen method) and pH 7.8. Two bread and two durum wheat varieties were adopted: Bologna and Solehio as bread wheat cvs, Antalis and Saragolla as durum wheat cvs. In each environment and in each crop season a randomized block design with three replicates was adopted with 4 genotypes and 13 fertilization treatments with a combination of 4 N rates (0, 80, 130, 180 kg/ha) and 4 strategies including three double applications (50% at tillering and 50% at stem elongation) of ammonium nitrate (AN split), ammonium sulphate nitrate (ASN split), ammonium sulphate nitrate with nitrification inhibitor (ASNi split), the latter also tested as single application at tillering (ASNi single). A list of agronomic and crop physiologic traits, were evaluated: grain yield (GY) and its components, grain N uptake (GNU), agronomic N efficiency (NAE), apparent recovery efficiency (ARE), partial nutrient balance (PNB), grain protein content (GPC), test weight (TW) and spectral vegetation indexes (VIs including NDVI, WI, EVI, PRI – ASD FieldSpec 2 and Trimble GreenSeeker). Means were separated by least significant difference ($p<0.05$) and analysis of the correlation was performed by JMP (SAS).

Results
The different environments were characterized by differences in thermal and rainfall distribution during crop season (629 mm TO20, 663 mm TO21, 215 mm FG20 and 246 mm FG21). This resulted in a higher

mean GY at TO than FG (5.3 t/ha and 8.3 t/ha at TO20 and TO21; 2.7 and 5.5 for FG20 and FG21). Overall, only Solehio in TO resulted in a higher GY, showing a better NAE and ARE. GPC was higher in Bologna and Antalis genotypes. The increase of N rate significantly increase GY and in higher extent GPC. The comparison between the different N fertilization strategies did not impact on GY and NUE, while only ASNI single showed a significant lower GPC. Significant relationships between NDVI and other VIs with GY and, especially, N uptake were observed (Figure 1). The correlation between NDVI and GY was higher at booting and decreasing with development, while in the ripening stages the higher correlation values were observed with GPC. The observed differences in crop productivity, sustainability and grain quality were dependent on the effects of environment, genotype and management.

Table 1. Effect of the genotype, environment and N fertilization on the investigated agronomic traits.

Factor	Level	NDVI			GY	GPC	N uptake	NAE	ARE	PNB
		4.5[a]	6.5	8.3	t/ha	%	kg /ha	kg / kg	%	-
Environment	TO-20	0.76 c	0.80 b	0.31 c	5.2 c	11.7 c	101.9 c	22.7 b	70.6 a	0.89 c
	TO-21	0.84 b	0.79 b	0.32 c	7.7 a	10.6 d	139.0 b	25.2 a	63.0 a	1.17 b
	FG-20	0.73 d	0.88 a	0.45 b	3.1 d	16.6 b	89.9 d	2.3 c	26.4 b	0.81 d
	FG-21	0.90 a	0.87 a	0.49 a	5.4 b	17.1 a	162.4 a	0.4 c	29.4 b	1.43 a
Genotype	Antalis	0.80 b	0.82 bc	0.34 c	5.2 b	14.1 ab	122.8 a	7.4 b	48.2 b	1.07 a
	Bologna	0.80 b	0.85 a	0.44 b	5.4 b	14.8 a	127.6 a	14.6 a	34.2 c	1.11 a
	Saragolla	0.82 a	0.82 c	0.29 d	5.3 b	13.6 b	120.0 a	8.5 b	44.4 bc	1.05 a
	Solehio	0.82 a	0.84 b	0.48 a	5.8 a	13.4 b	122.3 a	15.1 a	65.9 a	1.07 a
N rate (kg//ha)	0	0.71 c	0.73 c	0.33 b	4.0 c	12.2 c	88.9 d	-	-	-
	80	0.79 b	0.82 b	0.36 b	5.1 b	13.3 b	114.4 c	13.0 a	53.9 a	1.43 a
	130	0.81 a	0.82 a	0.40 a	5.5 a	14.1 a	128.0 b	11.2 ab	48.8 ab	0.98 b
	180	0.82 a	0.84 a	0.41 a	5.7 a	14.7 a	137.5 a	9.7 b	40.9 a	0.76 c
N strategy	AN split	0.81 a	0.84 a	0.40 a	5.4 a	14.4 a	129.7 a	11.6 a	52.2 a	1.09 a
	ASN split	0.81 a	0.84 a	0.39 ab	5.4 a	14.1 a	126.7 a	11.1 a	45.8 a	1.06 a
	ASNi split	0.80 a	0.83 a	0.38 ab	5.3 a	14.1 a	124.5 a	10.2 a	44.8 a	1.04 a
	ASNi single	0.80 a	0.83 a	0.37 b	5.3 a	13.8 b	123.1 a	10.0 a	44.1 a	1.03 a

[a] growth phenologic stage according to Zadoks scale: 4.5 = booting; 6.5 = anthesis; 8.3 = ripening.

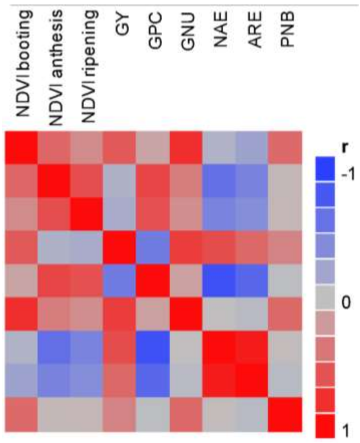

Figure 1 - Matrix of correlation

Conclusions

The spectral phenotyping carried out showed a good correlation between some physiological and yield investigated traits and the main VIs. The timing of phenotyping resulted a critical aspect to predict yield performance and N uptake in grains. Non-destructive spectral measurements assessing phenological and physiological varietal responses to different environmental conditions, can contribute to optimize agronomic management in relation to environmental sustainability, yield and quality. The use of special fertilizer (with nitrification inhibitor and/or S) did not result in a significant yield or qualitative difference, compared to the conventional split application as ammonium nitrate. Furthermore the different fertilization strategies, including the use of nitrification inhibitor, could play a key role in terms of mititgation of GHG emissions. Further analysis on gluten composition and technological quality are in progress.

Literature

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