Comparative analysis of tetraploid and hexaploid wheat for Nitrogen use efficiency and related traits under optimal and limiting Nitrogen condition

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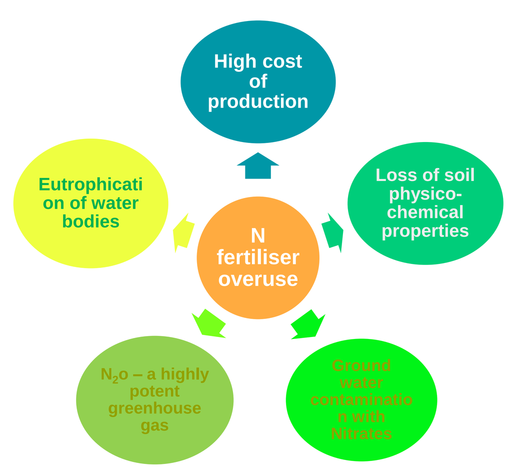
Introduction

- The realisation about the importance of efficient use of Nitrogen has started gaining pace recently due to negative effects on the environment and high cost associated with Nitrogenous fertilisers



- Nitrogen fertiliser constitutes about 57.1 percent of the total fertiliser consumption for agricultural purpose throughout the world and 65.1 percent in India (FAO, 2019)
- As per IFA assessment (2014-15), 18.2 percent of the global consumption of nitrogenous fertilisers was applied to wheat alone. In India, this figure stands at 23.5% (Heffer *et al.,* 2017).
- This undue application of Nitrogenous fertilisers has led to lower Nitrogen use efficiency for cereal crops in India (21%) in comparison to the global figures (35%) (Omara, 2019)
- Wheat genotypes vary with respect to the extent of metabolic and molecular changes that lead to differential growth of roots under low N conditions (Xu et al., 2019). The diversity of D genome is useful for tolerance to various abiotic stresses including water and nutrient uptake (Reynolds et al. 2007, Huang et al., 2007)
- It is essential to mine for new sources of NUE among the available wheat species and to improve the existing varieties for NUE

Objectives

(i) Dissection of traits contributing to Nitrogen use efficiency in the three cultivated species of wheat viz. *T. aestivum* L., *T. durum* Desf. and *T. dicoccum* (Schrank) Shuebl

(i) Identification of superior lines for NUpE and NUtE in the three cultivated spp. of wheat

Material

Forty four genotypes of wheat comprising 20 genotypes of *T. aestivum*, 13 genotypes of *T. durum* and 11 genotypes of *T. dicoccum*

Methods:

(a) Field experiment for above ground NUE and related traits

- Split plot design with two replications:
- ✓ Main plot- N level (N_{50} – 23.05 g per plot and N_{100} – 46.1 g per plot)
- ✓ Subplot- Genotypes (44)
- Environments- Two (Dharwad and Ugar)
- Software-ADEL-R (Pacheco *et al.,* 2018), META-R (Alvarado *et al.*, 2020)

(b) Root phenotyping for NUpE

- **Design**-Factorial CRD with 4 replications

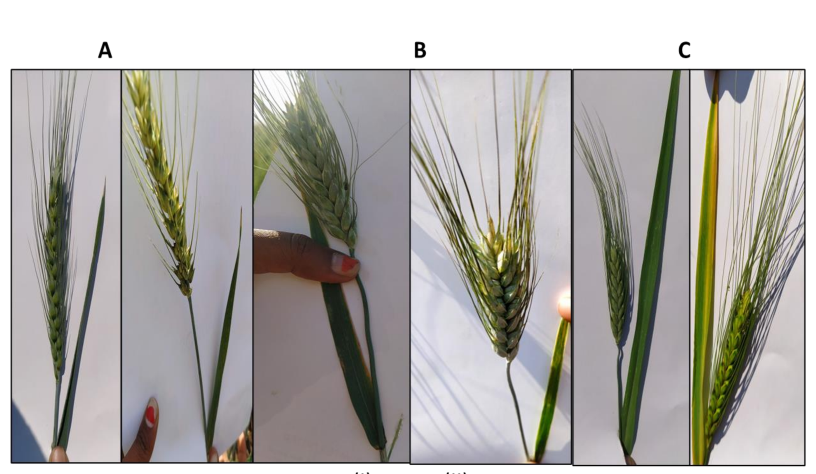
✓Factor 1-N level (N_{50} and N_{100})

✓Factor 2- Wheat species (*T. aestivum*, *T. durum* and *T. dicoccum*)

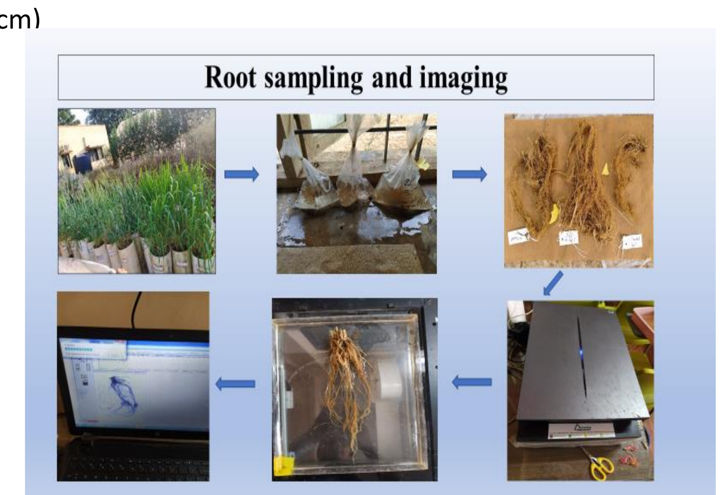
- **Location**- Rabi 2020-21 at Dharwad

Analysis- Two way analysis of variance using type III sum of squares

- **Phenotyping**- Epson flatbed scanner and WinRHIZO™ for image analysis at three different rooting depths- (top (0-30 cm), middle (30-60 cm) and bottom (>60 cm)



Visual observation of leaf greenness at (i) anthesis and (ii) grain filling in (A) *Triticum aestivum*, (B) *Triticum durum* , and (C) *Triticum dicoccum*



Results

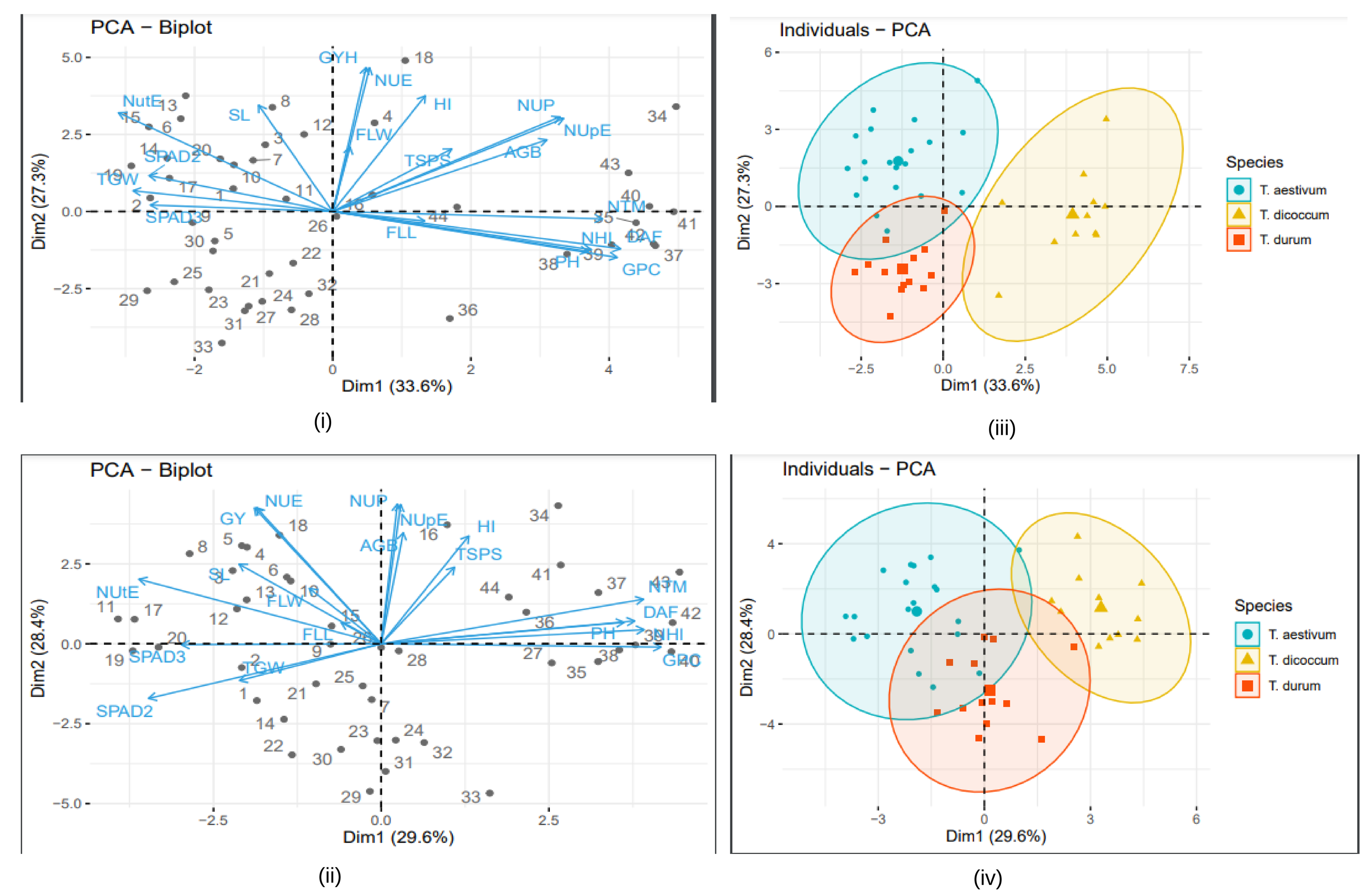


Figure 1: Biplot of the first two principal components (i (N_{50}) and ii (N_{100})), PCA of individuals (iii (N_{50}) and iv(N_{100})) based phenological and Nitrogen use efficiency traits for 20 genotypes of *Triticum aestivum*, 13 genotypes of *Triticum durum* and 11 genotypes of *Triticum dicoccum*

*Numbers 1-44 denote genotypes. Abbreviations-DAF-days to fifty percent flowering, SPAD2 and SPAD3- Chlorphyll content at flowering and grain filling stages respectively, FLW and FLL- Flag leaf length and width, SL-spike length, TSPS- Spikelets per spike, PH-plant height, TGW- Thousand grain weight, NTM- no. of productive tillers per metre, GY- grain yield per ha, AGB- above ground biomass per ha, HI-harvest index, NHI-N harvest index, GPC- grain proein content, NUP- Total N uptake, NUpE- N uptake efficiency, NUtE- N utilisation efficiency, NUE-Nitrogen use efficiency

Table 1: Best Linear Unbiased Estimates for top three genotypes in *Triticum aestivum, Triticum durum and Triticum dicoccum* for phenological traits and Nitrogen use efficiency at N_{50} with respect to the top performing checks

Genotype	Code	DAF	SPAD3	PH	NTM	TGW	HI	AGBH	GYH	NHI	NUP	NUpE	NUtE	NUE	GPC
High NUE Triticum aestuvm Checks															
UAS BW-13358	4	65.25	32.11	76.47	57	45.01	0.34	7190.9	2434.17	0.86	58.91	0.5	41.23	20.46	10.73
UAS BW-13356	8	63.25	41.47	73.13	50.25	49.25	0.33	7125	2362.99	0.8	67.08	0.56	35.24	19.88	10.88
UAS BW-13354	6	62.25	39.46	70.48	47.75	46.25	0.4	6024.65	2273.26	0.79	53.86	0.45	43.24	19.12	9.59
Triticum aestivum															
GW 322	18	63.75	33.66	72.79	53.5	43.75	0.34	8571.3	2913.86	0.84	72.49	0.61	40.51	24.35	10.52
DBW 14	13	62.5	48.36	64.78	50	41.5	0.4	5813.53	2423.91	0.79	60	0.5	39.63	20.19	10.52
UAS BW-13355	3	64	36.33	73.07	48	45.25	0.35	6518.78	2225.11	0.79	60.88	0.51	36.69	18.67	10.56
Triticum durum															
MLT DW RI 8	26	66.5	36.67	73.53	56.25	46	0.22	8120	1739.17	0.81	62.83	0.53	27.52	14.59	11.26
EC126374	22	66.25	35.16	73.65	48.25	48.13	0.25	5965.83	1433.33	0.83	49.23	0.41	29.93	12.03	11.79
UAS DW 30217	21	64.5	39.3	84.52	45.5	43.75	0.23	5867.5	1362.5	0.83	43.04	0.36	31.79	11.47	10.85
Triticum dicoccum															
NP 200	34	74.75	33.88	85.21	99.75	35.39	0.30	7568.5	2262.53	0.86	72.3	0.61	30.95	18.99	13.42
DDK-50421	43	74.75	38.59	91.05	83.75	38.78	0.29	6879.93	2011.72	0.85	69.75	0.59	28.47	17.04	14.26
DDK-50403	40	75.5	38.03	83.23	109.5	35.19	0.27	6565	1773.82	0.87	60.89	0.52	29.17	15.01	13.99

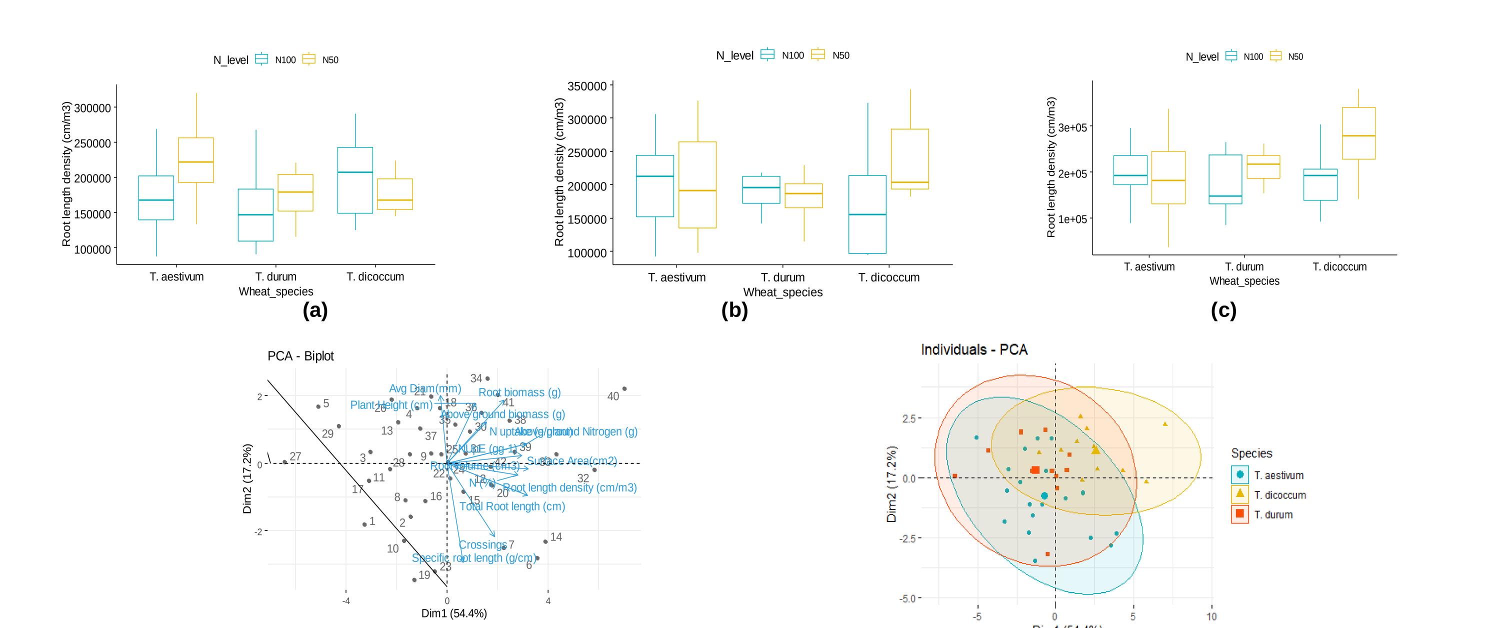


Figure 2: (A) Boxplots for root length density for *Triticum aestivum*, *Triticum durum* and *Triticum dicoccum* at N_{50} and N_{100} for (a) Top (1-30 cm), (b) Middle (30-60 cm) and (c) Bottom (>60 cm) zone of the soil column, (B) Biplot of the first two principal components (d) and PCA of individuals (e) at N_{50} based on root traits and Nitrogen uptake traits for 20 genotypes of *Triticum aestivum*, 11 genotypes of *Triticum durum* and 11 genotypes of *Triticum*

Table 2: : Response of top performing genotypes identified based on Nitrogen uptake efficiency for root traits and nitrogen uptake traits in *Triticum spp.* at moderate (N_{50}) and control (N_{100}) nitrogen supply and percentage change from N_{100} to N_{50}

S.No	Genotype	N level	NUpE (gg^{-1})	TRL (cm)	AD (mm)	RLD (cm/m^3)	RB (g)	SRL (g/cm^3)	N (%)	AGN (g)	NUP
Triticum aestivum											
15	WH 1022	N_{50}	0.52	5001.06	0.45	165378.83	1.03	4846.88	0.89	0.16	0.29
		N_{100}	0.42	6393.75	0.39	211433.47	1.06	6012.84	1.78	0.28	0.34
6	UAS BW-13354	N_{50}	0.51	8473.59	0.37	280211.28	1.97	4310.7	0.96	0.15	0.28
		N_{100}	0.32	4888.35	0.44	161651.67	1.24	3954.81	0.98	0.21	0.26
12	RAJ 4248	N_{50}	0.49	5785.73	0.45	191327.21	1.62	3567.21	0.88	0.15	0.27
		N_{100}	0.54	6501.17	0.41	214985.81	1.26	5179.6	1.49	0.35	0.44
% Change			-18.75%	-8.31%	3.53%	-25.20%	-43.60%	13.76%	25.51%	45.24%	19.23%
Triticum durum											
26	MLT DW RI 8	N_{50}	0.55	4611.34	0.34	152491.56	1.32	3505.64	0.8	0.17	0.3
		N_{100}	0.32	1999.66	0.57	66126.39	1.31	1529.23	0.83	0.21	0.26
32	UAS 446	N_{50}	0.48	5707.18	0.39	188729.45	2.58	2211.22	0.85	0.15	0.27
		N_{100}	0.49	7637.97	0.31	252578.51	1.55	4928.04	1.77	0.32	0.4
22	EC126374	N_{50}	0.48	4744.29	0.44	156887.87	1.15	4128.22	0.79	0.15	0.26
		N_{100}	0.33	3191.3	0.4	105532.39	1.28	2487.86	0.96	0.21	0.26
% Change			-32.46%	-17.41%	8.59%	-17.41%	-21.98%	-10.06%	31.46%	36.49%	9.78%
Triticum dicoccum											
43	DDK-50421	N_{50}	0.69	8743.53	0.51	289137.85	3.77	2320.19	1.24	0.21	0.38
		N_{100}	0.36	5572.23	0.48	184266.79	1.87	2977.32	1.33	0.24	0.29
34	NP 200	N_{50}	0.62	7910.94	0.44	261605.11	2.79	2835.6	1.53	0.19	0.34
		N_{100}	0.26	5669.99	0.53	187499.51	1.5	3784.91	1.04	0.17	0.21
35	DDK-50332	N_{50}	0.62	7966.69	0.41	263448.88	2.09	3811.77	0.93	0.19	0.34
		N_{100}	0.46	6809.22	0.59	225172.68	2.69	2529.39	1.3	0.3	0.37
	% Change		-78.70%	-36.39%	15.00%	-36.39%	-42.74%	3.49%	-0.82%	16.90%	-21.84%

Abbreviations: *NUpE -N uptake efficiency, TRL- total root length, AD- average diameter, RLD- root length desnity, RB- root biomass, SRL- specific root length, N (%)- *percent* Nitrogen, AGN- above ground Nitrogen, NUP- N uptake,

Discussion

- The study on the above ground phenotypic traits suggested that the three species show slightly differential response to variable N application. At N_{50}, grain yield per ha, flag leaf width, spike length, harvest index and N uptake had greater contribution to N UE as compared to other traits
- At N_{100}, NUtE also contributed to NUE in addition to grain yield, flag leaf width, spike length and N uptake. The PC analysis was done using the BLUEs from two environments
- The best performing genotypes in Triticum aestivum, Triticum durum and Triticum dicoccum were GW 322 (24.35 kg kg-1), MLT DW RI 8 (14.59 kg kg-1) and NP 200 (18.99 kg kg-1) respectively. GW-322 performed better than the checks whereas the best performing genotypes in durum and dicoccum wheat could not outperform the checks
- . Root length density was found to be an important trait whose variation at different depths of the soil governs the N uptake efficiency of a genotype
- The response of a species for a trait was dependent on the N level as well as the rooting depth.
- The best performing genotypes for N uptake traits in each species are shown in Table 2
- The relative importance of NUtE and NUpE to attain NUE depends on the level of N available. The change in the ranking of genotypes between the root studies and above ground phenotype studies also supports this explanation.
- NUtE and NUpE are equally important to design a genotype with high NUE

Conclusions and Perspectives

- On the basis of the available data on the phenological and NUE traits in *Triticum aestivum*, *Triticum durum* and *Triticum dicoccum* genotypes and their response at N_{50}, typical characterisation of NUE lines in the three species can be done. This will be helpful for selection for NUE in future programmes
- The current study delineates the importance of evaluation of roots at different depths instead of whole root systems and use of competitive N levels in NUE research so that the N use efficient varieties can perform equally well in the field at moderate N levels. A competitive N level refers to an amount where a genotype can give its best performance with limited N application without compromising the Benefit:cost ratio

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