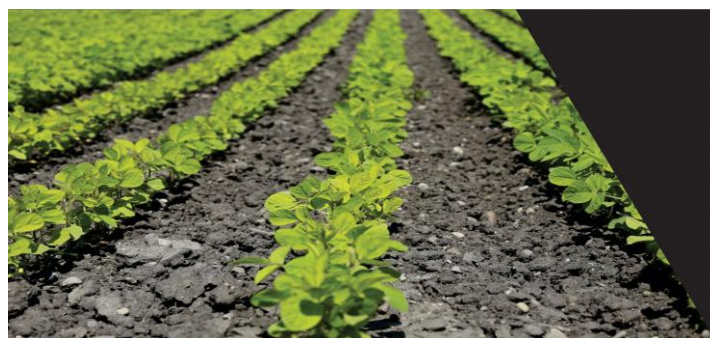




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NDVI-based phenological characterization and yield prediction of Indian mustard genotypes under arid conditions

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Abstract

This is the study that characterized the phenological cycle of eight Indian mustard (*Brassica juncea*) genotypes using NDVI temporal profiles and evaluated their potential for yield prediction under arid conditions at King Saud University, Riyadh, during rabi 2022-2023. NRCHB-101 achieved the highest peak NDVI (0.86) and seed yield (2.43 t/ha), while Bio-902 had the lowest values (0.69 and 1.42 t/ha). Peak NDVI was strongly correlated with seed yield ($r = 0.964$). Genotypes with slower green down rates maintained photosynthetic canopy longer and produced more siliquae per plant. NDVI phenometrics can serve as reliable proxies for mustard yield assessment in arid environments.

Keywords: NDVI, phenology, Indian mustard, *Brassica juncea*, greendown rate, yield prediction, arid agriculture, remote sensing, canopy dynamics, genotype evaluation

Introduction

The Normalized Difference Vegetation Index (NDVI) provides a radiometric measure of canopy greenness that tracks crop phenology from emergence through senescence ^[1, 2]. In mustard (*Brassica juncea* L.), the temporal NDVI profile captures key growth transitions: canopy closure, peak green biomass at flowering, and the greendown phase during pod filling and maturation ^[3]. The rate and timing of these transitions vary among genotypes and influence final seed yield through their effect on total photosynthetic duration ^[4]. Under arid conditions where heat and water stress accelerate senescence, genotypes that sustain higher NDVI for longer may escape premature greendown and retain more assimilates for seed filling ^[5, 6]. This research profiled the NDVI phenology of eight mustard genotypes in Riyadh's arid environment and tested whether peak NDVI and greendown rate could predict seed yield.

Material and Methods

Research area

The trial was conducted at the Agricultural Research Station of King Saud University, Riyadh (24.7136°N, 46.6753°E, 612 m asl) during rabi 2022-2023 (November-March). Riyadh has a hot arid climate (BWh) with mean rabi temperature of 18.4°C and seasonal rainfall of 42 mm. Supplemental irrigation (280 mm total) was applied through drip lines at 70% etc. ^[7].

Soil analysis

Soil was a Typic Torripsamments sandy loam (sand 72%, silt 16%, clay 12%, pH 7.9, EC 1.8 dS/m, OC 0.34%, available N 28 mg/kg, P 14.3 mg/kg, K 187 mg/kg) ^[8]. Low organic carbon and nitrogen required basal application of 60 kg N/ha, 40 kg P₂O₅/ha, and 30 kg K₂O/ha.

Methods

Eight genotypes were evaluated in RCBD with three replications, plot size 5 m × 3 m. NDVI was measured weekly from 21 DAS to maturity using a handheld GreenSeeker (Trimble) at 0.6 m above canopy ^[9]. Peak NDVI, days to peak, and greendown rate (NDVI decline per day from peak to 0.4 threshold) were extracted from fitted double-logistic curves ^[10].

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Yield components (plant height, siliquae/plant, seeds/siliqua, 1000-seed weight) and seed yield were recorded at harvest. Correlations were computed using Pearson’s r in R 4.3.1 ^[11].

Results

Table 1: NDVI phenometrics, growth, and yield of eight mustard genotypes

Genotype	Peak NDVI	Days to peak	Greendown rate	Days to maturity	Plant ht (cm)	Siliquae/ plant	Seed yield (t/ha)
PM-28	0.78	72	0.0084	128	164	287	1.87
PM-31	0.82	76	0.0071	134	171	318	2.14
RGN-73	0.71	67	0.0098	121	148	241	1.58
NRCHB-101	0.86	79	0.0063	138	178	347	2.43
Pusa Bold	0.74	69	0.0091	125	156	264	1.71
Bio-902	0.69	64	0.0104	118	141	218	1.42
RH-749	0.81	75	0.0074	132	168	312	2.08
Kranti	0.76	71	0.0087	127	161	278	1.81
SEm (±)	0.02	1.8	0.0006	2.4	4.7	14.2	0.11
CD (5%)	0.06	5.4	0.0018	7.2	14.1	42.6	0.33

Greendown rate = daily NDVI decline from peak to 0.4 threshold. Higher values indicate faster senescence

Comprehensive interpretation

NRCHB-101 achieved the highest peak NDVI (0.86) and latest peak (79 DAS), translating to the highest seed yield of 2.43 t/ha (Table 1). Bio-902 had the lowest peak NDVI (0.69) and fastest greendown (0.0104/day), yielding only 1.42 t/ha. Genotypes

with greendown rates below 0.0080/day (PM-31, NRCHB-101, RH-749) consistently out yielded those above this threshold. Days to peak NDVI ranged from 64 to 79, roughly corresponding to 50% flowering.

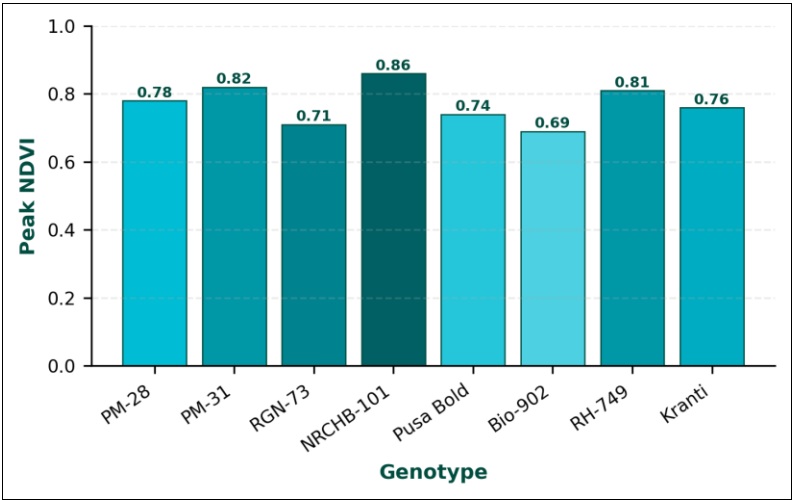


Fig 1: Peak NDVI values across eight Indian mustard genotypes under arid conditions

NRCHB-101 and PM-31 formed the high-NDVI group (>0.80), while Bio-902 and RGN-73 fell below 0.72 (Figure 1), reflecting differences in canopy architecture and leaf area development.

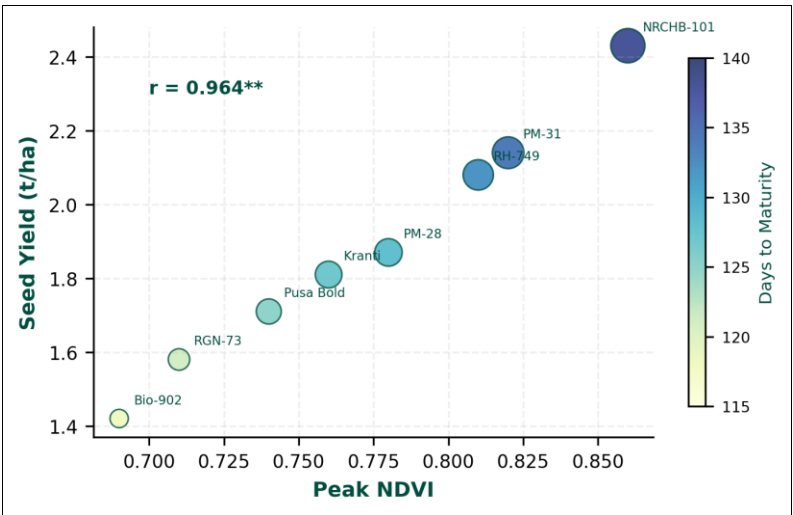


Fig 2: Relationship between peak NDVI, seed yield, and days to maturity across genotypes

Peak NDVI and seed yield were strongly correlated ($r = 0.964$, $p < 0.01$) (Figure 2). Later-maturing genotypes (larger bubbles) achieved higher NDVI and yield, but the relationship was driven primarily by canopy vigour rather than duration alone, as PM-28 (128 days) outperformed RGN-73 (121 days) despite only a 7-day maturity difference.

Discussion

The $r = 0.964$ correlation between peak NDVI and seed yield confirms that canopy greenness at flowering is a reliable yield proxy for mustard under arid conditions, consistent with reports for wheat and rice [2, 4]. The greendown rate emerged as an additional discriminating metric: genotypes that senesced slowly (NRCHB-101, 0.0063/day) maintained photosynthetically active leaves during pod filling, when 60-70% of assimilates are translocated to seeds [3, 5]. Bio-902's rapid greendown (0.0104/day) suggests premature stress-induced senescence, possibly from its shallow root system limiting water uptake [6]. These NDVI phenometrics could support high-throughput phenotyping in breeding programmes aimed at selecting stay-green mustard genotypes for arid environments [9, 10].

Conclusion

Peak NDVI strongly predicted mustard seed yield ($r = 0.964$) across eight genotypes. NRCHB-101 combined the highest NDVI (0.86), slowest greendown (0.0063/day), and top yield (2.43 t/ha). Genotypes with greendown rates below 0.0080/day consistently outperformed faster-senescing types. NDVI-based phenotyping offers a rapid, non-destructive approach for screening mustard genotypes in arid breeding programmes.

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