Overcoming soil water constraints to chickpea yield in rainfed environments of Western Australia and Bangladesh

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Declaration

I declare that this thesis is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary institution.

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Abstract

Chickpea (*Cicer arietinum* L.) is a major cool-season grain legume mainly grown in subtropical environments with summer-dominant rainfall or temperate environments with winter-dominant rainfall. In these environments, represented by the High Barind Tract of Bangladesh (HBT) and south-west Western Australia (WA), respectively, chickpea relies on either stored residual soil water or within-season rainfall. Limited soil water can constrain chickpea growth in both environments, from establishment to pod-fill. This thesis examines agronomic means of alleviating these stresses. It particularly considers the effects of newly introduced mechanised row-sowing and minimum tillage techniques in the HBT on soil water relations.

Plant population density (PPD) (modified through row spacing) and soil water content within the profile at sowing (modified through pre-season irrigation) were investigated in WA to determine how best to alleviate soil water stress. Additional profile soil water significantly improved crop yields through improved early biomass production, including increased ability of roots to extract water. Wider row spacing enhanced yield in a season of low rainfall, but when average rain fell during the season, pre-season irrigation did not alter the effect of row spacing on grain yield. This indicated that in-season rainfall was the main determinant of differential chickpea performance with row spacing.

In pot experiments, chickpea emergence was optimal at gravimetric soil water content of 17% and delayed when lower than 12% or higher than 23%. Soil strength impeded early root growth at >1 MPa, causing lateral roots to predominate. Seedling shoots tolerated high soil strength better than emerging radicles. In the HBT, with one-pass machine planting, soil water contents in the range 12 to 24% did not limit emergence of chickpea in the HBT across a wide sowing window (22 November to 22 December). However, the optimum sowing date for suitable seedbed conditions and to avoid limiting weather conditions during later vegetative and reproductive growth was found to be between 30 November and 10 December.

Mechanised one-pass row-sowing, permits earlier sowing than under traditional broadcast, full tillage techniques, when soil water contents are higher. In this study the tillage types which
disturbed the soil most, created a better seed-bed under high soil water contents and thus had greater success in chickpea emergence. Where soil water content in the seed-bed was moderate to marginal, emergence was not different between zero, strip and line sowing with full rotary tillage, but was better than traditional broadcast with full rotary tillage. Further, chickpea grain yields were higher with mechanised row-sowing than with traditional broadcast with full rotary tillage.

In the HBT, profile soil water content (0 to 50 cm depth) at podding was lower than wilting point, after this time chickpea accessed water from deeper in the soil profile. In some cases the extraction of soil water at depth later in the growing season was different between tillage treatments; these differences were attributed to differences in PPD. The investigation of PPD and profile soil water content provide insight into possible benefits to alteration in row spacing in the HBT, an environment with high initial soil water content in the profile and very little in-season rainfall. In such conditions wider row spacing may be of benefit as was the case in the WA trials under lower rainfall conditions.
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List of Abbreviations

100 cm row spacing 100RS
23 cm row spacing 23RS
50 cm row spacing 50RS
75 cm row spacing 75RS
above-ground biomass water use efficiency WUE
analysis of variance ANOVA
Agricultural Production Systems Simulator APSIM
Boron Bo
Botrytis grey mould BGM
bulk density $\rho_b$
change in water storage $\Delta W$
cone diameter $d_p$
crop lower limit CLL
cumulative evapotranspiration ET$_{cum}$
days after sowing DAS
Decision Support System for Agrotechnology Transfer DSSAT
drainage D
dry weight DW
emergence E
evapotranspiration ET
flowering FL
force $F$
fresh weight FW
grain water use efficiency GWUE
gravimetric soil water content $\theta_g$
gravimetric soil water content at an air-filled porosity of 10 % $\theta_{a|f|p}$
harvest index HI
High Barind Tract HBT
Irrigated IRR
leaf water potential LWP
least limiting water range LLWR
least significant difference l.s.d.
maximum root growth pressure $\sigma_{max}$
Molybdenum Mo
Nitrogen N
New South Wales NSW
non-irrigated NON-IRR
not significant n.s.
number of samples n
parameters of the water release curve equation (Van Genutchen 1980)

- constant $n$
- constant $m$
- degree of saturation $S_e$
- inverse of air entry potential $\alpha$
- residual water content $\theta_r$
- saturated water content $\theta_s$

- penetrometer resistance $Q_p$
- percentage clay clay %
- percentage sand sand %
- percentage silt silt %
- physiological maturity PM
- plant population density PPD
- podding PD
- power tiller operated seeder PTOS
- precipitation use efficiency PUE
- pre-season irrigation PRE-IRR
- probability $P$
- profile soil water content SWC
- rainfall P
- relative water content RWC
- residual maximum likelihood REML
- rice retained $RR$
- root growth pressure $\sigma$
- root length density RLD
- row spacing RS
- scaled frequency SF
- single pass shallow tillage SPST
- soil surface runoff R
- soil water potential $\psi$
- sowing S
- sowing date trial SD
- specific root length SRL
- standard error S.E
- strip tillage ST
- stubble $S$
- Sulphur $S$
- summer fallow rainfall SFR
- Systemic Acquired Resistance SAR
- tillage type trial TT
- Transplanted Aman rice T. Aman
- triple superphosphate TSP
- turgid weight TW
- two-wheel tractor 2WT
- versatile multi-crop planter VMP
- volumetric soil water content $\theta_v$
- volumetric soil water content at water potential of -10kPa field capacity $\theta_{fc}$
volumetric soil water content at water potential of -1500 kPa wilting point $\theta_{wp}$
volumetric soil water content from MP406 probe $\theta_{probe}$
Western Australia WA
zero tillage ZT
Zinc Zn
List of Botanical Names

barley
black gram
chickpea
common vetch
cotton
dry bean
faba bean
field pea or dry pea
lentil
linseed
lupin
maize
marshmallow
mungbean
mustard
narbon bean
pearl millet
pigeonpea
rice
ricegrass
ryegrass
sorghum
soybean
wheat
wild radish

(Hordeum vulgare L.)
(Vigna mungo L. Hepper)
(Cicer arietinum L.)
(Vicia sativa L.)
(Gossypium hirsutum L.)
(Phaseolus vulgaris L.)
(Vicia faba L.),
(Pisum sativum L.)
(Lens culinaris Medikus)
(Linum usitatissimum L. Griesb.)
(Lupinus angustifolius L.)
(Zea mays L.)
(Malva parviflora)
(Vigna radiata L. R. Wilczek)
(Brassica campestris L.)
(Vicia narbonesis L.)
(Pennisetum glaucum L.)
(Cajanus cajan L.)
(Oryza sativa L.)
(Oryzopsis holciform (M.B.) Richt.)
(Lolium rigidum)
(Sorghum bicolor L. Moench)
(Glycine max L. Merr.)
(Triticum aestivum L.)
(Raphanus raphanistrum)
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