Phosphorus nutrition of chickpea under dry topsoil conditions as in the High Barind Tract of 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 education institution.

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Abstract

In many parts of the world, notably in South Asia, crop intensification is resulting in more crops being grown on stored soil moisture, under which conditions the topsoil commonly dries out during crop growth. In the Mediterranean climatic region also, topsoils dry out particularly during the later part of the growing season. Implications of the drying of topsoils for crop nutrition in general are poorly understood. Crop intensification in South Asia is also leading to increased mechanisation and the emergence of minimum tillage sowing of crops. The key research question for the present thesis is availability of phosphorus (P) for chickpea grown with stored residual soil water in the context where placement of P fertilizer with the seed is accomplished by mechanised planters. This study investigated the P nutrition of chickpea considering uptake from topsoil and subsoil and factors affecting P availability, distribution and remobilization throughout the growing season when P fertilizer was supplied with the seed or below the seed (in the subsoil) under well-watered and dry topsoil conditions. Short-term (up to 12 or 24 days) glasshouse studies assessed the risk of toxicity for seed emergence and early growth of chickpea when P fertilizers were placed with seed in well-watered soil. In sand, seed-placed P fertilizers (diammonium phosphate and triple superphosphate) depressed chickpea germination and seedling growth while seed-placed P was safe in sandy clay loam soil at rates equivalent to 20 kg P/ha even in the scenario where the seed was sown in wide rows (up to 60 cm) that results in higher effective P fertiliser concentration around seed. In the field when chickpea was sown in four soils (sandy clay loam- clay loam texture) with a drying surface, the seed-placed P fertilizer at 20 kg P/ha as triple superphosphate had no suppressive effect in the early growth stage of chickpea but the grain yield improvement was very small (~10% over the nil P). Under a drying topsoil, chickpea accumulated P until late pod filling stage irrespective of P fertilizer treatments. From the accumulated P, plants remobilized a substantial amount of P (52% of total in vegetative shoot parts) which contributed the equivalent of 69% of the total pod P. The remobilization of P from the vegetative parts was not

sufficient for the pod P requirement but rather concurrent P uptake from the soil was needed to complete the P requirements of the pods. These results suggested that continual P uptake of chickpea depended on uptake from the subsoil P where moisture was available after drying of the topsoil. To assess the contribution of subsoil P to P uptake by chickpea under dry topsoil condition, a glasshouse study was setup by supplying P levels in the subsoil (10-30 cm). This study also showed that chickpea continued to accumulate P until late podding stage when the topsoil was completely dried; the pod P content was contributed by both remobilized P (70%) and concurrent uptake of P (30 %), but the level of P in the dry topsoil had no effect on total P content of the plant or its pods. Fractionation of P in rhizosphere soil showed that chickpea depleted sparingly-soluble 0.1 M NaOH-extractable inorganic P (NaOH Pi) in addition to labile P fractions. The drawdown of depleted P fractions was greater in the subsoil than the topsoil. The response of carboxylate exudation of chickpea under dry topsoil condition was investigated in the final glasshouse study. Under dry topsoil condition, chickpea exuded substantially higher amounts of total carboxylates in the well-watered subsoil compared to the dry topsoil. Malonate was the principal form of carboxylate followed by malate and citrate. The depletion of sparingly-soluble P forms (NaOH Pi from both the P-supplied topsoil and subsoil and the 1 M HCl extractable inorganic P from the subsoil without added P) suggests a link between the carboxylates excreted in the subsoil rhizosphere and the depletion of sparingly soluble P fractions. In conclusion, chickpea continued to take up P during the whole period of dry matter accumulation including during pod filling. Under conditions where the topsoil dried out mostly before flowering, the post-flowering P uptake is most likely to have been acquired from the subsoil. In this study, substantial root growth and carboxylate exudation by chickpea into the moist subsoil has been demonstrated suggesting a possible mechanism for mobilisation of subsoil P reserves for uptake during pod filling. The seed-placed P fertilizer had limited positive effect on chickpea grain yield in the field possibly due to shallow depth of fertilizer placement into topsoil which was dry when the plant's P demand was high. Subsoil placement of P fertilizer showed promise for improving P uptake and grain yield of chickpea under dry topsoil condition. Further studies are required under different soils and environmental conditions to assess the contribution of subsoil P to the P nutrition of chickpea.

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Abbreviations and Symbols

%	Per cent
~	Approximately
<	Less than
>	Greater than
≥	Greater than-equal
µmol	Micromole
2-WT	Two-wheel tractor
4-WT	Four-wheel tractor
Al	Alumunium
ABA	Abscisic acid
ANOVA	Analysis of variance
ASPAC	Australasian Soil and Plant Analysis Council
ATP	Adenisine triphosphate
B	Boron
BARI	Bangladesh Agricultural Research Institute
BGM	Botrytis grey mould
Ca	Calcium
cm	Centimetre
CRD	Completely randomized design
CV	Coefficient of variation
DAP	Di-ammonium phosphate
DAS	Day after sowing
DDI	Double de-ionized water
dS/m	Deci Siemen per metre
DW	Dry weight
FAO	Food and Agriculture organization
Fe	Iron
g	Gram
ha	Hectare
HBT	High Barind Tract
HI	Harvest index
ICARDA	International Centre for Agricultural Research in the Dry Areas

ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
K	Potassium
kg	Kilogram
Km	Kilometre
lsd	Least significant difference
m	Metre
M	Molar
m^2	Square metre
MAP	Mono-ammonium phosphate
MCP	Monocalcium phosphate
Mg	Magnesium
mL	Mililitre
mm	Milimetre
Mn	Manganese
Mo	Molybdenum
N	Nitrogen
n	Number of observation
ns	Non-significant
^oC	Degree Celcius
P	Probability
P	Phosphorus
PEPC	Phosphoenol pyruvate carboxylate
Pi	Inorganic phosphorus
Po	Organic phosphorus
PRI	Phosphorus retention index
r^2	Regression coefficient
RCBD	Randomized complete block design
S	Sulphur
SD	Standard deviation
SI	Salt index
SSP	Single superphosphate
t/ha	Tonne/hectare
T. aman	*Transplanted aman*
TCA	Tricarboxylic acid

TSP	Triple superphosphate
VAM	Vesicular-arbuscular mycorrhiza
vs	Versus
WA	Western Australia
Zn	Zinc

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