OPTIMISATION OF DRY BEAN (*Phaseolus vulgaris* L.) SEED PRODUCTION UNDER GREENHOUSE CONDITIONS

JUSTICE CHANDHLA

JUSTICE CHANDHLA

OPTIMISATION OF DRY BEAN (*Phaseolus vulgaris* L.) SEED PRODUCTION UNDER GREENHOUSE CONDITIONS

MSc (Agronomy) UP 2001

OPTIMISATION OF DRY BEAN (*Phaseolus vulgaris* L.) SEED PRODUCTION UNDER GREENHOUSE CONDITIONS

BY

JUSTICE CHANDHLA

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR

THE DEGREE OF MASTER OF SCIENCE (AGRIC): AGRONOMY

Department of Plant Production and Soil Science

in the

FACULTY OF NATURAL AND AGRICULTURAL SCIENCES

UNIVERSITY OF PRETORIA

PRETORIA

SEPTEMBER 2001

TABLE OF CONTENTS

ACKNOWLEDGEMENTS ..... **iv**

ABSTRACT ..... **v**

CHAPTER 1

GENERAL INTRODUCTION

1.1 INTRODUCTION 1

1.2 REFERENCES 3

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL 4

2.2 THE BEAN PLANT 4

2.3 PLANT GROWTH AND DEVELOPMENT 6

2.4 REPRODUCTION IN BEANS 8

2.5 YIELD AND YIELD COMPONENTS 8

2.6 CARBOHYDRATE SYNTHESIS 10

2.7. FACTORS AFFECTING PRODUCTION 10

2.8. GROWTH REGULATORS IN BEAN PRODUCTION 17

2.9 REFERENCES. 18

CHAPTER 3

SEED YIELD AND YIELD COMPONENTS OF DRY BEAN AS AFFECTED BY PLANT DENSITY UNDER GREENHOUSE CONDITIONS

3.1 INTRODUCTION 26

3.2 MATERIALS AND METHODS 27

3.3 RESULTS 31

3.4 DISCUSSION 38

3.6 CONCLUSION 39

3.7 REFERENCES 40

CHAPTER 4

SEED YIELD AND YIELD COMPONENTS OF DRY BEANS AS AFFECTED BY SPACING UNDER FIELD CONDITIONS

4.1 INTRODUCTION 43
4.2 MATERIALS AND METHODS 44
4.3 RESULTS 47
4.4 DISCUSSION 61
4.5 CONCLUSION 63
4.6 REFERENCES 63

CHAPTER 5

EFFECT OF NITRATE / AMMONIUM RATIO AND CONCENTRATION ON VEGETATIVE GROWTH, SEED YIELD AND YIELD COMPONENTS OF DRY BEAN UNDER GREENHOUSE CONDITIONS

5.1 INTRODUCTION 66
5.2 MATERIALS AND METHODS 67
5.3 RESULTS 71
5.4 DISCUSSION 88
5.5 CONCLUSION 91
5.6 REFERENCES 91

CHAPTER 6

EFFECT OF A CYTOKININ-CONTAINING GROWTH REGULATOR ON SEED YIELD AND YIELD COMPONENTS OF DRY BEAN

6.1 INTRODUCTION 94
6.2 MATERIALS AND METHODS 95
6.3 RESULTS AND DISCUSSION 96
6.4 CONCLUSION 106
6.5 REFERENCES 106

CHAPTER 7

GENERAL DISCUSSION AND CONCLUSION

7.1 PLANT DENSITY 108
7.2 NITROGEN SOURCE AND CONCENTRATION 109
7.3 CYTOKININ-CONTAINING GROWTH REGULATOR 111
7.4 FUTURE RESEARCH 111
7.5 REFERENCES 111

SUMMARY 113
OPSOMMING 116
APPENDIX 119

ACKNOWLEDGEMENTS

I am deeply indebted and grateful to Prof. P.S. Hammes for his able supervision, encouragement and constructive criticism throughout the period of this study. 'You have made a difference in my professional career'.

I am also grateful to the Ministry of Agriculture Food and Fisheries of the Government of the Republic of Zambia (GRZ) through the IFAD / GRZ sponsored Southern Province Household Food Security Programme for the scholarship.

My gratitude is also extended to Prof. A.S. Claassens for his technical help in the development of some experiments.

I want to extend my gratitude to the Dry Bean Producers' Organisation (DPO) and Dr D.J.Theron for provision of seed used in the execution of this study and for suggesting the research topic.

My sincere thanks to Mr E. A. Beyers, Mr J.M. de Beer (post humously), and their staff for the daily logistical support at the Greenhouse, Phytotron, and field station.

To my wife, Grace Zulu Chandhla, my children Lauretta, Reuben, Janet, Zindaba and Mathangeni, my brother Sanida , sister Brenda and sister in law Claire for their patience and endurance in support of my study. I love you all.

To my parents, relatives and family friends for their encouragement.

I would also like to acknowledge the spiritual support of the Andrew Murray Dutch Reformed Church of Pretoria throughout my study period.

Finally to the University of Pretoria for according me the opportunity to "savour" its knowledge and facilities and to the "Rainbow nation" South Africa for the hospitality.

OPTIMISATION OF DRY BEAN (*Phaseolus vulgaris* L.) SEED PRODUCTION UNDER GREENHOUSE CONDITIONS

BY

JUSTICE CHANDHLA

SUPERVISOR: Prof P.S. HAMMES

DEPARTMENT: Plant Production and Soil Science

DEGREE: MSc (Agric.) Agronomy

ABSTRACT

Means of optimising dry bean seed production under greenhouse conditions were investigated using two dry bean cultivars, Kranskop and Teebus. The objective was to optimise dry bean seed multiplication in the greenhouse with the view to multiplying disease free dry bean seed. The effect of plant density on seed yield and yield components was determined. Furthermore, the influence of different nitrate / ammonium ratios and their concentration in the nutrient solution were quantified. Finally, the effect of a cytokinin-containing growth regulator, a seaweed extract, was also evaluated.

Seed yield m^{-2} increased linearly with increasing plant population, until a plant density of 139 plants m^{-2} was reached, beyond which no further increase was observed. A seed yield of 823.6g m^{-2} was produced. This was associated with a steady decrease in seed yield per plant and number of pods per plant. The number of seeds per pod and the seed size remained stable with a small decrease observed at very high plant densities.

The nitrate / ammonium ratio affected vegetative growth, seed yield and yield components. Plants receiving the nutrient solution containing 14:1 and 1:1 NO_3^-: NH_4^+ ratios grew vigorously and produced seed yields of 19.1g and 21.2g per plant respectively, while those receiving the nutrient solution containing 1:14 NO_3^-: NH_4^+ ratio produced only 7.3g of seed per plant. No significant differences were observed among plants receiving the different nutrient solution concentration treatments. However, plants receiving the full strength and half strength nutrient solutions produced seed yields of 16.2g and 16.0g per plant respectively, while those receiving the quarter strength nutrient solution yielded 15.5g per plant. The results indicate that the half strength nutrient solution containing either 1:14 or 1:1

NO_3^-: NH_4^+ ratios would be the most cost effective.

Treatment with a cytokinin-containing growth regulator, a seaweed extract (trade name Marinure) at the recommended and double rates did not effect seed yield and yield components under greenhouse conditions.

KEY WORDS: Plant density, Nitrate / ammonium ratio, concentration, nutrient solution, cytokinin-containing growth regulator.

SUMMARY

The effect of plant density, nitrate / ammonium ratio and concentration and a cytokinin-containing growth regulator on vegetative growth, seed yield and yield components of dry bean were studied in a series of pot experiments and a plant density field trial.

Plant density

One pot experiment, two crate experiments and a field experiment were undertaken to study the effect of plant density on vegetative growth, seed yield and yield components of beans.

Pot experiment

Cultivars Teebus and Kranskop were planted in one litre pots filled with a clay loam soil. Plant densities of 42 and 29 plants m^{-2} were established using spacings of 15.5 x 15.5 cm and 18.5 x 18.5 cm in the greenhouse. The seed yield per unit area of cultivar Teebus increased from 232g to 321g m^{-2} while that of cultivar Kranskop increased from 283g to 360g m^{-2} as plant density increased from 29 to 42 plants m^{-2}. No cultivar differences were observed. Seed yield per plant did not differ between cultivars nor between plant densities.

Crate experiment 1

Three plant densities of 44, 25 and 16 plants m^{-2} were established by planting cultivar Kranskop at spacings of 15 x 15 cm, 20 x 20 cm and 25 x 25 cm in crates of size 60 x 55 x 20 cm. Seed yield per unit area increased from 354 to 581g m^{-2} as plant density increased from 16 to 44 plants m^{-2} while seed yield per plant decreased from 22.1 to 13.1g.

Crate experiment 2

High plant densities of 200, 139, 100 and 69 plants m^{-2} were established by planting cultivar Kranskop at spacings of 10 x 5, 12 x 6, 10 x 10 and 12 x 12 cm in crates of size 60 x 55 x 20 cm. Seed yield per unit area increased from 462 to 822g m^{-2} as plant density was increased from 69 to 139 plants m^{-2}, beyond which seed yield declined to 783g m^{-2}. Seed yield per plant decreased from 6.6 to 3.9g per plant as plant density increased from 69 to 200 plants m^{-2}.

Field experiment

Cultivars Teebus and Kranskop were planted in a systematic planting design where the position of plants were determined by the intersection of radii and arcs of concentric circles. The growing area occupied by each plant increased systematically as the radius increased. Seed yield data was recorded from four adjacent radii at each concentric circle for each plant population of 2.5, 4.2, 6.2, 8.3, 11.1, 12.5 16.7, 25 and 33.3 plants m^{-2}. Seed yield per unit area increased as plant density increased while seed yield per plant remained relatively stable for both cultivars. However, cultivar Kranskop yielded somewhat more seed per plant than cultivar Teebus at all plant densities.

Nitrate / ammonium ratio

Two pot experiments were conducted to determine the effect of nitrate / ammonium ratio and the concentration of nutrient solutions on vegetative growth, seed yield and yield components of dry bean cultivar Kranskop

Pot experiment 1

Cultivar Kranskop was planted in 10 litre Mitscherlich pots filled with sterilised sand. The plants were supplied with 14:1 and 1:1 NO_3^-: NH_4^+ ratios at full strength and half strength nutrient solution concentrations. Although differences were observed in vegetative growth of the crop due to different NO_3^-: NH_4^+ ratios and nutrient solution concentrations, no differences were observed in seed yield and yield components.

Pot experiment 2

In the second experiment cultivar Kranskop was planted in 8 litre pots filled with sterilised sand. The plants were supplied with 14:1, 1:1 and 1:14 NO_3^-: NH_4^+ ratios at full strength, half strength and quarter strength nutrient solution concentrations. Vegetative growth decreased with decreasing nutrient solution concentration, while plants receiving high NH_4^+-N (1:14 NO_3^-: NH_4^+ ratio) showed poor vegetative growth compared to those in the other treatments. Plants receiving the nutrient solutions containing 14:1and 1:1 NO_3^-: NH_4^+ ratios at full strength and half strength concentrations performed far better than those receiving the nutrient solution containing a higher ammonium ratio or any of the nutrient solutions at the quarter strength.

Cytokinin-containing growth regulator

The cytokinin-containing growth regulator, a seaweed extract, was applied at the recommended rate of 8ml per 1 litre nutrient solution, double rate of 16ml per 1 litre nutrient solution and a control (no growth regulator) to plants grown in 8 litre pots filled with sterilised sand. Data for vegetative growth, seed yield and yield components was recorded and analysed. Vegetative growth, seed yield and yield components were not affected by the different growth regulator treatments applied.

The more important conclusions from these trials are:

i. The relative high seed yields of 580g m^{-2} and 822g m^{-2} obtained with the cultivar Kranskop is indicative of the viability of greenhouse multiplication in the dry bean seed multiplication programme. Very high plant populations (up to 139 plants m^{-2}) are indicated. However, the optimum plant population for commercial multiplication will depend on a number of factors which include cultivar, container size, nutrition and convenience of management.

ii. A nitrate / ammonium ratio in the nutrient solution with more ammonium than nitrate detrimentally affected yield. The results indicate that good yields can be obtained with nitrate/ammonium ratios of 14:1 or 1:1. Similar yields were obtained with the nutrient solutions at the full strength and half strength, indicating possible cost savings by applying diluted nutrient solutions.

iii. Application of a cytokinin-containing growth regulator did not increase seed yield. The use of plant growth regulants to limit abscission of flowers and pods deserves more research attention.

OPSOMMING

Die invloed van plantdigtheid, die nitraat / ammoniak verhouding in die voedingsmedium en die effek van 'n sitokinien bevattende groeireguleerder, op vegetatiewe groei, saadopbrengs en opbrengskomponente van droëbone is ondersoek.

Plantdigtheid

Een potproef, twee proewe in plantkratte en 'n veldproef is onderneem om die effek van plantdigtheid op vegetatiewe groei, saadopbrengs, en opbrengskomponente te kwantifiseer.

Potproef

Kultivars Teebus en Kranskop is in een liter potte, gevul met 'n kleileem grond, geplant. Plantdigthede van 42 en 29 plant m^{-2} is verkry met spasiërings van 15,5 x 15,5 cm en 18,5 x 18,5 cm in die kweekhuis. Die saadopbrengs per eenheidsoppervlakte van die kultivar Teebus het verhoog vanaf 232g m^{-2} na 321g m^{-2}, terwyl dié van kultivar Kranskop verhoog het vanaf 283g m^{-2} na 360g m^{-2} namate die plantdigtheid verhoog het vanaf 29 na 42 plant m^{-2}. Saadopbrengs per plant het nie verskil tussen die kultivars en die plantdigthede wat gebruik is nie.

Kratproef 1

Drie plantdigthede van 44, 25 en 16 plante m^{-2} is verkry deur kultivar Kranskop te plant met spasiërings van 15 x 15 cm, 20 x 20 cm en 25 x 25 cm in kratte van 60 x 55 x 20 cm grootte. Saadopbrengs per vierkante meter het verhoog van 354 na 581g m^{-2} namate die plantdigtheid verhoog het vanaf 16 na 44 plante m^{-2}, terwyl die saadopbrengs per plant terselfdertyd afgeneem het vanaf 22,1 na 13,1g.

Kratproef 2

Hoë plantdigthede van 200, 139 en 69 plante m^{-2} is gevestig deur kultivar Kranskop te plant in spasiërings van 10 x 5, 12 x 6, 10 x 10 en 12 x 12 cm in kratte van 60 x 55 x 20 cm grootte. Saadopbrengs het verhoog vanaf 462 na 822g m^{-2} namate die plantdigtheid verhoog is vanaf 69 na 139 plante m^{-2}. Saadopbrengs per plant het afgeneem vanaf 6,6g per plant tot 3,9g per plant namate die plantdigtheid verhoog het vanaf 69 na 200 plante m^{-2}.

Veldproef

Kultivars Teebus en Kranskop is geplant in 'n wawiel-uitleg waar die posisie van die plante bepaal is deur die interseksie van radiusse en boë van konsentriese sirkels. Die groei-area wat opgeneem is deur elke plant het dus sistematies vergroot namate die radius verleng het. Saadopbrengs is bepaal by populasies van 2.5, 4.2, 6.2, 8.3, 11.1, 12.5, 16.7, 25 en 33.3 plante m^{-2}. Saadopbrengs per eenheidsoppervlakte het verhoog namate die plantdigtheid verhoog het, terwyl saadopbrengs per plant relatief stabiel gebly het vir beide kultivars. Kranskop het ietwat meer saad per plant geproduseer as Teebus.

Nitraat / ammoniak verhouding

Twee potproewe is gedoen om die effek van nitraat / ammoniak verhoudings en konsentrasies van voedingsoplossings op groei, saadopbrengs en opbrengskomponente van droëboon kultivar Kranskop te bepaal.

Potproef 1

Saad van kultivar Kranskop is geplant in 10 liter Mitscherlich potte, gevul met gesteriliseerde saad. Die plante is voorsien met voedingsoplossings met 'n 1:14 NO_3^- : NH_4^+ verhouding of 'n 1:1 NO_3^- : NH_4^+ verhouding. Die voedingsoplossings is teen volle sterkte (die aanbevole konsentrasie) en teen half sterkte toegedien.

Alhoewel verskille waargeneem is in vegetatiewe groei as gevolg van die NO_3^- : NH_4^+ verhouding en nutriënt konsentrasie, is geen verskille waargeneem in saadopbrengs en opbrengskomponente nie.

Potproef 2

In die tweede proef is kultivar Kranskop geplant in 8 liter potte gevul met gesteriliseerde saad. Die plante is benat met voedingsoplossings met 'n 1:14, 'n 1:1 en 'n 14:1 NO_3^- : NH_4^+ verhouding teen volle sterkte, half sterkte en kwart sterkte van die voedingsoplossings. Vegetatiewe groei het afgeneem met verlaagde voedingsoplossing konsentrasies, terwyl die plante wat hoë NH_4^+ -N ontvang het genieg was om swakker vegetatiewe groei te ontwikkel as dié in die ander behandelings. Plante wat die 1:14 verhouding en die 1:1 verhouding teen volle sterkte en half sterkte ontvang het, het hoër opbrengste gelewer as behandelings met die hoë NH_4^+ - konsentrasie, of waar 'n kwart van die standaard voedingsoplossing konsentrasie

gebruik is.

Sitokinien-bevattende groeireguleerder

'n Sitokinien-bevattende groeireguleerder is toegedien teen die aanbevole peil van 8ml per 1 liter asook teen 16 ml per 1 liter voedingsoplossing. Vegetatiewe groei, saadopbrengs en opbrengskomponente is nie geaffekteer deur die verskillende groeireguleerder-behandelings nie.

Die belangrikste gevolgtrekkings van hierdie ondersoek is:

I. Die relatiewe hoë saadopbrengste van 580 g m^{-2} en 820 g m^{-2} wat met die kultivar Kranskop verkry is in die glashuisproewe dui op die lewensvatbaarheid van 'n glashuis-vermeerderingsfase in 'n droëboon saad-program. Baie hoë plantpopulasies (139 m^2) het die beste resultate gelewer. Die optimum plantpopulasie vir kommersiële vermeerdering sal afhang van faktore soos kultivar, kratgrootte, voeding, ensovoorts.

II. 'n Mengsel van NO_3^--N en NH_4^+-N met dieselfde hoeveelheid of meer NO_3^- as NH_4^+ word aanbeveel. Die resultate dui daarop dat die standaard voedingsoplossing-konsentrasie onnodig hoog is, en dat dieselfde opbrengste behaal kan word deur die voedingsoplossing teen halfsterkte toe te dien.

III. Geen verbetering in opbrengs is verkry met die gebruik van 'n sitokinien-bevattende groeireguleerder nie. Die gebruik van plantgroeistowwe om afspening van blomme en jong peule te beperk verdien egter verdere navorsingsaandag.