# THE EFFECT OF WATER STRESS ON WATER RELATIONS, CARBON ISOTOPE DISCRIMINATION, AND SHOOT AND ROOT GROWTH OF SAINFOIN (*Onobrychis viciifolia* Scop.) AND LUCERNE (*Medicago sativa* L.)

A thesis presented
in partial fulfilment of the requirements
for the degree of Doctor of Philosophy in Department of Plant Science
at Massey University

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1994

بسم الله الرحمن الرحيم

الحمد لله رب العالمين

والصلاة والسلام على خاتم الأنبياء والمرسلين

**In the name of Allah,**

**the Compassionate, the Merciful,**

**Prise be to Allah, Lord of the Universe,**

**And Peace and Prayers be upon**

**His final Prophet and Messenger.**

# ABSTRACT

Sainfoin (*Onobrychis viciifolia* Scop.) is a useful forage legume regarded as having drought resistant attributes. Also, it does not cause bloat in ruminants and is not sensitive to alfalfa weevil (*Hypera postica.* L). Although the physiological and morphological responses to water stress of lucerne (*Medicago sativa* L.) are well known the responses of sainfoin to water stress have not been fully studied. In this study the physiological and morphological responses of sainfoin to water stress were investigated, with lucerne used as a reference plant.

The results of the indoor and outdoor studies showed sainfoin had useful characteristics for forage production in dry conditions. Relative to lucerne it had a lower yield, due to lower leaf area, lower stem number and poor regrowth. However, sainfoin responded to water stress at least as well as lucerne. Sainfoin had a higher root:shoot ratio and a lower specific leaf area ratio than lucerne, indicating a higher allocation of carbohydrate to the roots, and a lower leaf surface area for transpiration in sainfoin than for lucerne. Water stress decreased the yield of lucerne proportionally more than sainfoin mostly due to the greater reduction in the above ground dry weight of lucerne.

The indoor study of root characteristics of sainfoin and lucerne in 1m tall tubes showed that in terms of root development sainfoin responded to water stress better than lucerne. Although sainfoin had equal root mass and root length to lucerne, the root distribution of sainfoin at below 0.6 m depths was greater than for lucerne. As water stress developed sainfoin roots grew below 0.6 m earlier than lucerne roots. Sainfoin had a higher root osmotic adjustment than lucerne and also maintained higher (less negative) leaf water potential than lucerne.

The stomatal resistances (Rs) of sainfoin and lucerne were equal, but Rs was not distributed equally between adaxial and abaxial leaf surfaces. The Rs of the adaxial leaf surface of sainfoin was lower and more sensitive to water stress than the Rs of the abaxial leaf surface. The different Rs of the adaxial and abaxial leaf surfaces of sainfoin was partly due to the different stomatal frequencies of the respective surfaces.

Comparison of sainfoin cultivars in a climate room showed that the water use efficiencies (WUE) of Remont, Fakir, Cotswold-Common, and Eski, were similar. Remont was more sensitive to water stress than the other three cultivars, and Eski produced a greater root length and mass than other cultivars. The growth of Eski was initially slower than that of the Remont in both the indoor and the outdoor studies. However, lucerne grew faster than all the sainfoin cultivars. Over three harvests in the field the yields of Eski and Remont were similar but lucerne out yielded both sainfoin cultivars. Sainfoin produced a greater proportion of its yield earlier than lucerne, whereas lucerne distributed its yield throughout the whole season, indicating that sainfoin is adapted to regions with precipitation in only winter and spring.

The results of the carbon isotope discrimination ($\Delta$) analysis for the indoor and outdoor studies showed $\Delta$ had a negative correlation with WUE, leaf water potential, osmotic potential, and stomatal resistance, but had a positive correlation with relative water content, turgor potential, transpiration rate, and photosynthetic rate. These correlations demonstrated the usefulness of this technique for evaluating the responses of plants to water stress. The stressed plants always had lower $\Delta$ than the control plants showing the higher WUE of stressed plants. The $\Delta$ of roots was higher than the $\Delta$ of the leaves suggesting that the growth of leaves occurred in conditions that were an average drier than for the growth of roots. This was supported by the lower (more negative) water potential of leaves than roots. The $\Delta$ of the roots below 0.6 m depth was higher than the $\Delta$ of roots above 0.1 m depth suggesting the roots above 0.1m grew under higher water stress than the roots below 0.6m depth. Over three harvests in the field the $\Delta$ of Eski and lucerne were similar and the $\Delta$ of Remont was higher than for Eski and lucerne.

In conclusion, sainfoin was found to have several useful attributes for growth and survival in dry regions. Of the sainfoin cultivars examined Eski was the best adapted to water stress. Relative to lucerne, sainfoin yielded less, but had a similar water use efficiency, a shorter season of growth, a greater root: shoot ratio, deeper roots and better maintenance of leaf water potential under water stress.

# ACKNOWLEDGEMENT

First of all I would like to express my deepest sense of gratitude to almighty Allah, whose kindness and blessing helped me to do this study. Praise be to the final prophet Mohammad (peace upon him) and other messengers of Allah who were the righteous guidance of the human beings. I am grateful to my parents who taught me the first words and showed me the way of school on the first day of my study.

Thanks are extended to my chief supervisor Professor J. Hodgson for his excellent guidance and support during the last four years. Any time I needed his help I was provided a friendly answer. I have never felt any problems during this study due to his invaluable help and support.

I have no words to express my appreciation for the enthusiastic, helpful, friendly, and scholastic supervision of my two co-supervisors Drs. P. D. Kemp and D. J. Barker. The great patience and considerable attention of these two great men shown at regular meetings over four years is highly appreciated. Without their strong, and tireless efforts, this work could never have been finished. To me, this has been an invaluable educational experience, any errors remaining in this thesis, are entirely mine.

I acknowledge the assistance given to me by the following:

- Drs. I. L. Gordon (Department of Plant Science), and S. Ghaneshanandam (Department of Statistics) for statistical advice.
- Professor G. D. Farquhar and his group (Research School of Biological Science, Australian National University (ANU)) for their very useful discussion and comments, allowing me to work in their laboratory, analysing the samples for carbon isotope discrimination, teaching me the carbon isotope discrimination technique, and their warm hospitality during my training

course at ANU.

- Professors W. Silvester, and A. Rajendram Carbon Isotope Unite (University of Waikato, ) for analysing samples for carbon isotope discrimination.
- Professor R. G. Thomas (Department of Plant Biology) for his advice and comments on stomatal frequency reported in this thesis.
- Drs. C. A. Cornford and D. W. Fountain (Department of Plant Biology) for teaching me plant water relations.
- Associated Professor A.C.P. Chu and Dr. C. Matthew (Department of Plant Science) for their comments, discussions, and sympathetic support.
- Drs. D. R. Scotter, and D. J. Horne (Department of Soil Science) for teaching me soil water relationships and allowing me to work in their laboratory.
- Mr L. D. Currie (Department of Soil Science) for measurements of soil fertility used in this study.
- Technicians of the Plant Science Departments: Ms. F. Brown for her excellent assistance with laboratory work on growing rhizobium and rhizobium inoculation, and Mrs. C. Mckenzie for drawing the templates and providing facilities.
- Mrs. S. Cleland for patiently and carefully estimating leaf area, and for measurements of leaf water potential.
- The Manager of Plant Growth Unit (P.G.U.) Mr. R. Johnston and staffs of P.G.U. in particular technical assistance of C. Forbes, and G. Russell during the experiment. I will never forget the immediate and positive response of Mr. Johnston to all of my requests and his famous sentence: Nothing is impossible.
- Mr. B. Mckay for writing the computer programs for the manipulation of the data from the porometer, and Li–Cor 6200.
- Ag-Research for permission to use the facilities which made this study possible.
- The staff of Hort-Research in particular those in the Climate Room Services, and the Technical Service team for prompt and efficient service.
- Mr. T. Lynch and M. Osborne (Plant Science Department) for Technical

assistance with the field experiment and refurbishment of the Rain-out shelter.

- Dr. D.J. Barker for lending the Decagon, and TDR, and his assistance with the for preparation of the figures in this thesis.
- Dr. H. Behboudian for lending the Wescor, and his excellent advice and comments.
- The late Dr. M. Forde and Montana State University for providing sainfoin seed.
- All postgraduates and members of Plant science Department who provided me an excellent and friendly environment and removed all difficulties.
- The staff of the Massey University Computer Center for their cooperation.
- All members of the International Muslim Association at Massey, in particular Iranian, Pakistanian, and Indonesian brothers and their families who created a pleasant and religious work environment for me and my family.

Special thanks are extended to my wife Nosrat for her patience, loyal support, sacrifices and understanding in allowing me to pursue my study during last decade in tranquillity. I am also grateful to my beloved daughter Zeinab and my son Ali for their patience, forbearance and submissiveness during this study.

Finally the financial support (full scholarship) of the Ministry of Jahad Sazandegi (Iran) for undertaking this study is highly appreciated.

This dissertation is dedicated to the martyrs of the Islamic Republic of Iran who presented their life to Allah and irrigated the tree of Islam by their blood.

# LIST OF ABBREVIATIONS:

A= Assimilation rate (μmol $CO_2/m^2/s$)

ABA= Abscisic Acid

ANOVA= Analysis of variance

$C_a$= $CO_2$ concentration of the air (ppm)

$C_i$= $CO_2$ concentration inside of the leaf (ppm)

$C_s$= Stomatal conductance (cm/s)

D= drainage

DAP= Days after planting

DS= Days of stress

DW= Dry weight

E= Transpiration rate (mol $H_2O/m^2/s$)

$e_a$= Vapour pressure of the air

$e_i$= Vapour pressure of the leaves

FR= Fine roots (<0.3 mm diam.)

GSWC= Gravimetric soil water content (%)

I= Interception of rainfall by crop canopies

LA= Leaf area ($cm^2$)

LAI= Leaf area index

LDW= Leaf dry weight (g)

P= Turgor potential (MPa)

$P_a$= Partial pressure of $CO_2$ concentration of the air (MPa)

$P_i$= Partial pressure of $CO_2$ concentration of the leaf (MPa)

$P_n$= Net photosynthetic rate (μmol $CO_2/m^2/s$)

R= run-off

$R_s$= Stomatal resistance (s/cm)

RH= Relative humidity (%)

RSE= Relative stem elongation (mm/mm/day)

RWC= Relative water content of the leaf (%)

RWD= Root weight density ($g/m^3$)

SDW= Stem dry weight (g)

SLA= Specific leaf area ($cm^2/g$)

SEM= Standard error of the mean

S/R= shoot:root ratio

TAC= Total available carbohydrate

TDR= Time domain reflectometer

TR= Thick roots (>0.3 mm diam.)

Tr= Transpiration rate (ml $H_2O$)

VPD= Vapour pressure deficit

VSWC= Volumetric soil water content (%)

W= Transpiration efficiency {($\mu$mol $CO_2/m^2/s$)/(mol $H_2O/m^2/s$)}

WUE= Water use efficiency

$Y_{ec}$= Economic yield

$\Delta$= Carbon isotope discrimination

$\pi$= Osmotic potential (MPa)

$\pi_{100}$ = Osmotic potential at full turgor (MPa)

$\upsilon$= Water vapour pressure difference between the intercellular spaces and the atmosphere

$\phi$= Loss of carbon or water not through stomata

$\Psi$= Leaf water potential (MPa)

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