Literature review exploring the options of herbs in grasslands in the Netherlands

Effects on resilience and robustness of cattle and the ability to cope with heat stress

M.J. Groot

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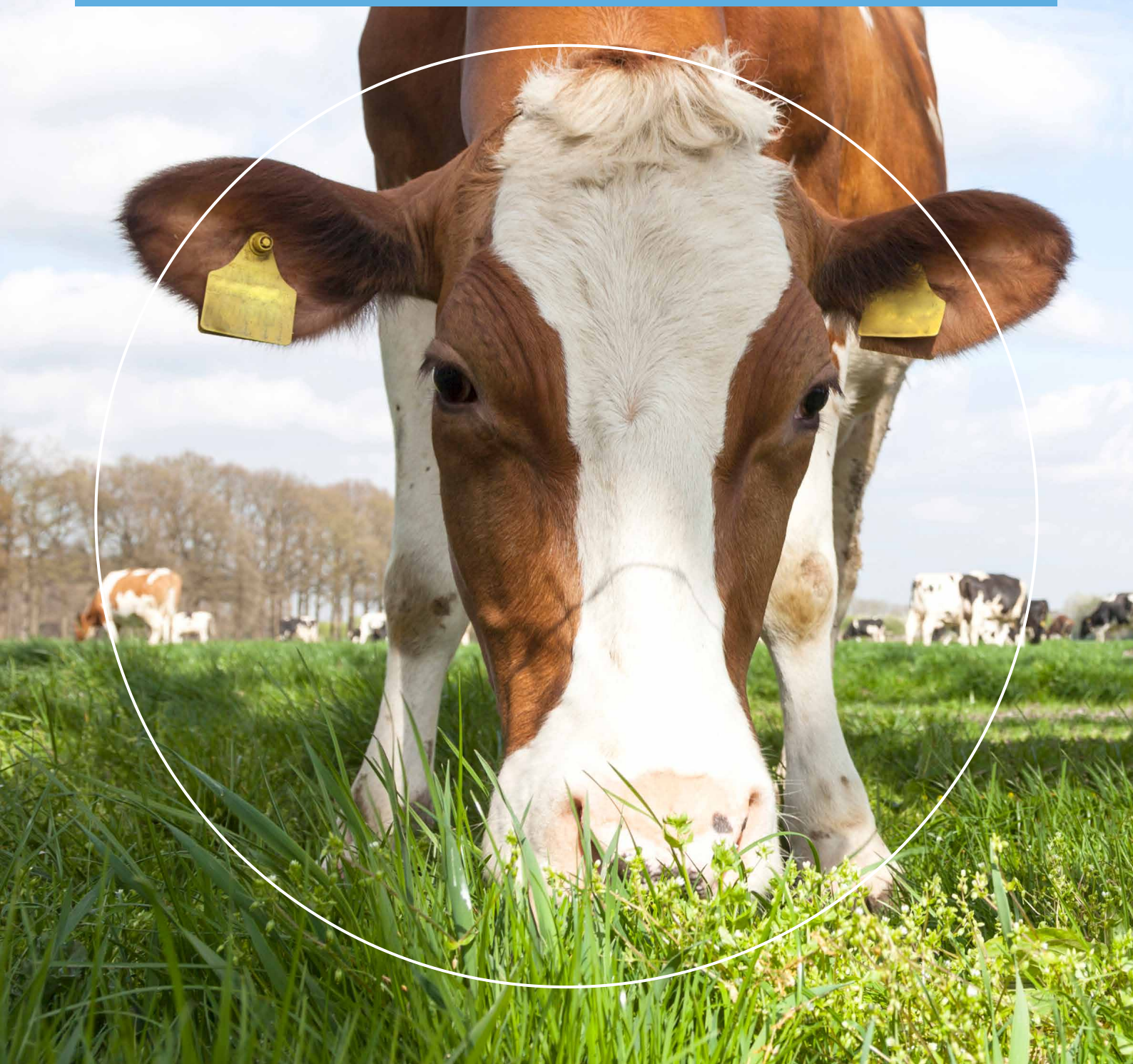

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Contents

Summary

Within the framework of the Knowledgebase Program 34 (Circular and Climate Neutral), this literature review presents information about herbs in Dutch pastures that can contribute to heat stress reduction in cattle. For dairy cattle there is growing interest in herbal pastures, both to increase biodiversity and to support animal health. In this review the focus is on the effects of these plants on cattle 'resilience' and their ability to cope with heat stress.

To achieve this a literature review was performed using the following method: based on an existing database of plants in grassland, PubMed, Scopus and some handbooks on veterinary phytotherapy were searched for effects of the mentioned plants on resilience and heat stress in cattle. Finally, promising plants are listed with their common and botanical name, their constituents, their biological action and indication according to standard works on phytotherapy.

Positive effects on 'resilience' are defined as positive effects on appetite, digestion, anti-inflammatory, antiphlogistic, anti-oxidant, spasmolytic, blood purifying, analgesic, anxiolytic, antimicrobial, immune-modulating effects, effects on liver (cholagogue), effects on kidneys (diuretic) and high levels of vitamins (vitamin C, B, A). Literature was searched for plants that specifically affect the animals ability to cope with heat stress and plants containing high levels of vitamin C, anxiolytic effects and appetite stimulating effects were also considered as having a positive effect.

The results show that promising pasture herbs for increasing resilience include common dandelion, stinging nettle, shepherd's-purse, chamomile, red clover, white clover, plantain, soft-brome, cuckoo flower, milk thistle, forget me not daisy, common chickweed, cow parsley, salad burnet, yarrow, fennel, lady's bedstraw, corn chamomile, chicory, common sainfoin, dill, caraway, parsley, black medick, alfalfa, fenugreek, hedge bedstraw and London rocket.

An easy solution to prevent heat stress in cows is to provide pastures with trees and shrubs. If trees and shrubs cannot be provided, pasture plants researched for biochemical effects specifically on heat stress according to literature are dill, chicory, London rocket and fenugreek. Herbs like Shepherd's-purse, chamomile, plantain, milk thistle, daisy, common chickweed, fennel and caraway could also contribute to the ability of dairy cows to cope with heat stress based on their biological actions. However, it depends on the availability in the pasture and the amount of plant material that the animals eat whether the plants can achieve the effects listed in the aforementioned literature. This should be further investigated.

Moreover, other herbs and herbal extracts of plants, not native to the Netherlands, can contribute to reduction in heat stress, such as rosemary, cinnamon, turmeric, clove buds, Psyllium, white wormwood, cornus, thyme and oregano. Extracts or grounded products of these herbs could be used as complementary feed. In conclusion many promising herbs for cattle health and resilience have been identified, as well as herbs with a possible effect on the cows' ability to cope with heat stress. These plants can be part of the meadow biodiversity or fed as complementary feed. Further investigation is needed to evaluate the effects of these plants in the fields or used as complementary feed in practice under Dutch circumstances.

Conclusions
- Many grassland herbs can exert positive effects on animal health and resilience
- Research showing health effects of biodiverse pastures is scarce
- Some plants can affect the ability of animals to cope with heat stress
- Best results were obtained with plant(extracts) added to the feed

Recommendations
- Research on effects of specific combinations of herbs in herbal grassland on cow health under Dutch circumstances
- Research on the effects of plants added to the feed on heat stress under Dutch circumstances

1 Introduction

For dairy cattle there is growing interest in herbal pastures. Herbal pastures are characterized by biodiversity in plant species (such as herbs) rather than English Rye grass being the sole grass species. This biodiverse diet can contribute directly to the health of the animal and, indirectly, through its plant secondary metabolites and its better mineral supply (Pirhofer-Walzl et al., 2011). Biodiversity in the diet is mirrored in the biodiversity of the gut and rumen microbiome, leading to more resilient animals. Biodiverse pastures also have deeper root systems, more diverse soil life, better water retention capacity and are more draught resistant (Koorevaar and Geerts, 2016) which makes them very valuable in combatting the effects that climate change has on grazing systems. In 2020 we made a spreadsheet with an overview of plants in grasslands, their main components, health effects and potential toxic effects and literature. In this review the focus is on the effects of these plants on resilience and the ability to cope with heat stress in cattle.

2 Materials and methods

The plants mentioned in this review are based on a spreadsheet with meadow plants, biological actions and health effects composed by Davide Angelucci in 2020, and some additions from literature. Literature was searched for effects of the mentioned plants on resilience and heat stress in cattle via Pubmed and Scopus and some handbooks on veterinary phytotherapy. Plant databases used for biological activities and constituents were Liber Herbarum II from Erik Gotfredsen and Dukes Phytochemical and Ethnobotanical databases. Search terms were cattle, health, resilience, heat stress, and the botanical name of the plant.

Positive effects on resilience include positive effects on appetite, digestion, anti-inflammatory, antiphlogistic, anti-oxidant, spasmolytic, blood purifying, analgesic, anxiolytic, antimicrobial, immune-modulating effects, effects on liver (cholagogue), effects on kidneys (diuretic) and high levels of vitamins (vitamin C, B, A). Literature was searched for plants with specific effects on heat stress. Moreover plants containing high levels of vitamin C, with anxiolytic and appetite stimulating effects were considered as having a positive effect on the ability to cope with heat stress.

3 Results

In Table 1, the plants that can occur in herbal pastures are mentioned with their botanical name, main constituents, biological action and indication according to phytotherapeutical handbooks. Based on these data in Table 2 the possible effects on resilience and heat stress are listed.

Table 1 *plants from herbal pastures with their constituents and possible effects, plants with toxic properties are in orange.*

Name	Part used	Constituents	Biological action	Indication	References
Alfalfa (*medicago sativa)*	Herb, feed	Alpha-Spinasterol, Biochanin A, Cerebroside, pinitol, Galactomannan, Myricetin, apigenin, Quinic acid, Beta-Sitosterol, geraniol, betain, cholin, biotin, adenin, rutin, coumarins	Adaptongenic, tonic, remineralising, hemostatic, diuretic, cholesterol-lowing, aperitivum, spasmolytic, immune stimulant	Tonicum, Skin problems, bleeding problmes, oedema, anorexia, indigestion, infections of the urinary tract	Liber herbarum II, Verhelst (2019)
Birdsfoot trefoil (*Lotus corniculatus L.)*	Herb Toxic for sheep and cattle!	Canaline, canavalia gibberellin, hydrogen cyanide, cyanogenic glycosides, condensed tannins	Anti-pyretic, sedative, Anti-inflammatory, Antiphlogisticum, Hyperglycemia, cardiac, Anti-spasmodic, restorative, Anthelmintic, Carminative, Herbal tonic	Small quantities can improve digestion and respiration	Liber herbarum II Plants for the future
Bitter dock (*Rumex obtusifolius*)	Leaf, root	Nepodin, vitamin C, neral, tannic acid, potassium oxalate	Cathartic, skin diseases	None	Liber herbarum II
Black medick (*Medicago lupulina)*	Herb	None of importance	Antiseptic		Liber herbarum II,
Caraway (*Carum carvi L.*)	Herb, seeds, root	Carvone, limonene, phellandrene, beta-pinene in essential oil, quercetin, phytosterols	Carminative, antispasmodic, galactagogue	Anorexia, indigestion, flatulence, colic, to improve milk secretion	Liber herbarum II
Chamomile (*Matricaria chamomilla A, Matricaria recutita*)	Flowers	Chamulenic acid, alpha-bisabolol, sesquiterpenes, apigenin, kaempherol, tannins, rutin, hyperoside, quercitine, coumarins	Anti-spasmodic, Carminative, anti-inflammatory, anti-phlogistic, digestive, anxiolytic, antipruritic, cholagogue, antiallergic, healing	Indigestion, inflammation in the gut, colic, nausea, stress, anxiety, bloating	Liber herbarum II, Verhelst (2019), Wynn and Fougere 2007. Brendieck-Worm and Melzer (2018)
Chicory (*Cichorium intybus L.)*	Root	Bitter substances, cholin, cichoriin, tannic acid, Lactucopicrin, inulin, phenylpropane derivates, flavonoids	Appetizer, cholagogue, liver protective, digesticum	Indigestion, anorexia, biliary disorders, liver disease	Liber herbarum II Brendieck-Worm and Melzer (2018)

Name	Part used	Constituents	Biological action	Indication	References
Cow parsley (*Anthriscus sylvestris)*	Herb	Anthricin, essential oil, Deoxypodophyllotoxin., dihydroanhydropodorhizol, Isoarborinol, Nodakenin, podophyllotoxin, vit. A, B2	Diuretic, tonic, sleep, wound healing	Indigestion, colic, wounds	Liber herbarum II
Common chickweed (*Stellaria media)*	Herb	Calcium, potassium, flavonoid, minerals, saponins, mucilage, coumarin	Depurative, cough, cooling, rheumatism, Mucolytic agent	Wounds, skin problems, respiratory problems	Liber herbarum II
Common dandelion (*Taraxacum officinale*)	Root and leaves	sesquiterpene lactone, triterpenes, taraxol, taraxerol, carotenoids, lutein, inulin, saponins, taraxinic acids, myristic acid, flavonoids, apigenin, luteolins, chrysoeriol, minerals, (potassium), phenolic acids, coumarins, sitosterol, stigmasterol, taraxasterol, vit A., quercetin glycosides	Diuretic, cholagogue (leaf), Root: laxative, cholagogue. Reduction interleukin-6, decrease TNF alpha (anti-inflammatory) Increasing appetite, digestion, antimicrobial, antiphlogistic, spasmolytic, Blood purifying. Immune modulation, Anti-oxidant effects	Digestive tonic, liver support, edema, diuretic	Wynn and Fougere 2007. Brendieck-Worm and Melzer (2018) Kour et al., (2016) Majewski et al., (2020)
Common plantain (*plantago major*) and Narrow leaved plantain (*Plantago lanceolata*)	Rherb	Baicalein, Baicalin, Hispidulin, Indicaine, Nepetin, Plantagonine, Scutellarin, Tyrosol, allantoin, alkaloid, asperuloside, vitamin C, aucubin, Catalpol, Silicic acid, choline, citric acid, Emulsin, tannic acid, resin, Chlorogenic acid, Luteolin, Oleanolic acid, rhamnose, salicylic acid, mucilage, tannins, essential oil	Depurative, wound healing, anorexia, expectorans, diuretic	Tonic, wounds, respiratory disorders, cough, bronchitis, diarrhea	Liber herbarum II, Verhelst (2019),
Common sainfoin (*Onobrychis viciifolia Scop.)*	Herb, feed	Proanthocyanidine, flavonoids, rutin, arbutin, isoliquiritigenin, isorhamnetin-3-O-rutinoside, phosphatidylinositol, phosphatidylethanolamine, phosphatidylserine	Anthelmintic, wound healing	Internal parasites, festing wounds	Brendieck-Worm and Melzer (2018) Liber herbarum II
Corn chamomile (*Anthemis arvensis L.)*	Herb, flowers	Essential oil (isobutyl-angelicate, pinocarvone) nobiline, polyphenols, apigenin, coumarins, catechol derivates	Anti-pyretic, anthelmintic, spasmolytic, digestivum, anti-inflammatory	Indigestion, stomatitis, gingivitis	Liber herbarum II
Cuckoo flower (*Cardamine pratensis*)	Herb	Bitter Components, glucosinolates, minerals (Fe, Mg, K) mustard oil, Mustard oil compounds, vitamin C	Depurative, diuretic, indigestion, anti-spasmodic, anti-rheumatic	Edema, indigestion, colic, arthritis	Liber herbarum II

Name	Part used	Constituents	Biological action	Indication	References
Daisy (*Bellis perennis*)	Herb and roots	Beta-Sitosterol, Bitter Components, tanning agents, tannic acid, inulin, saponins, mucilage, essential oil,	Depurative, constipation, anti-spasmodic, mucolytic agent, wound healing, antimicrobial, nervous system, dermatological, anti-inflammatory, cytotoxic, antioxidant, hypolipidemic, antihemorrhagic, hemolytic	Wounds, skin problems, gastro-intestinal problems	Liber herbarum II, Ali Esmail Al-Snafi (2015)
Dill (*Anethum graveolens L.)*	Herb, seeds	Essential oil, limonene, carvon, eugenol, anethol, dillefurane, dihydrocarvone, alpha- and beta-phellandrene, betasitosterol, kaempherol, dillasonide, coumarins, triterpenes, phenols, Dillapiol, Caryophyllene, bergaptene, D-Limonen	Carminative, antispasmodic, stomachic, galactagogue, diuretic, anti-emetic	Anorexia, colic, indigestion, nausea, dyspepsia, to improve milk secretion	Liber herbarum II Verhelst (2019),
Fennel (*Foeniculum vulgare Mill.)*	Herb, fruits, seeds	Volatile oil, phenylpropanids, anethole and estragole, phenolic acids, flavonoids, furanocoumarins, fenchone,	Aromatic, stomachic, antispasmodic, carminitative, expectorans, galactogogue, antimicrobial	Digestive problems, flatulence, fragrance and flavouring, improves digestion, respiratory problems, especially young animals	Liber herbarum II Brendieck-Worm and Melzer (2018) Wynn and Fougere 2007.
Fenugreek (*Trigonella foenum-graecum L.)*	Herb, seeds	Essential oil, trigonelline, choline, diosgenin, yamogenin, tigogenin, neotigogenin, steridoal saponins	Alterative, carminative, demulcent, hypoglemic, laxative, expectorans, galactagogue, antidiabetic, antioxidative, hypocholesterolemic, hypoglycemic, anti-inflammatory, antiulcerogenic, antitumor and immunomodulatory	Diabetes, to improve milk production, immune modulation, hyperlipidemia, poultice for wounds, indigestion, bronchitis, gastric ulcers, tonic, anorexia	Liber herbarum II, Wynn and Fougere 2007 Satheeshkumar et al., 2010
Forget Me Not *Myosotis spp. (arvensis, scorpiodes*)	Herb	Alkaloids, tannic acid, potassium	Sedative, anti-inflammatory, wound healing, Convalescence, adstringent, stimulant	Diarrhea, skin problems, bruises, nose bleed, stimulant, inflammation of bowels	Liber herbarum II
Hedge bedstraw (*Galium Mollugo)*	Herb, flowers	Mollugin, hesperidin	Anti-spasmodic, wound healing	Indigestion, wounds	Liber herbarum II,
Lady's bedstraw (*Galium verum L.)*	Herb	Aucubin, flavonoid, saponins, counarins, asperuloside, tannins, nicotinic acid, anthraquinine, monotropein	Diuretic, Anti-pyretic, anticonvulsant, wound healing, adstringent, anti-inflammatory, lymphatic	Oedema, diarhea, skin problems, swollen lymph nodes	Liber herbarum II Wynn and Fougere 2007

Name	Part used	Constituents	Biological action	Indication	References
London rocket (*Sisymbrium irio L)*	Herb, leaves, seeds	Flavonoids, Glucosinolate, beta-sitosterol, beta-sitosteryl-D-glucoside, Isorhamnetin, quercetin, sitosteryl-60 -Oundecanoate--D-glucoside, (Z)-8,11,12-trihydroxyoctadec-9-enoic acid	Antipyretic, Wound healing, tonic, expectorant, mucolytic, stimulant	Abdominal pain, fever, wounds, Cough, eye disease	Liber herbarum II, Dukes, Plants for the future
Milk thistle (*Silybum marianum*)	seed	Bitter Components, flavonoid, histamine, minerals, Silibinin, Silychristine, silymarin, Silydianin, mucilage, tyramine, essential oil, apigenine, quercetin, kaempferol	Emetic, cholagogue, galactogogue, antioxidant, demulcent, anti-lipid peroxidation, hepatoprotective, anti-inflammatory, antifibrotic, nephroprotective, spasmolytic	Intoxications, biliary disorders, indigestion. Icterus, liver support, liver disease. Kidney support, control blood lipids, dyspepsia	Liber herbarum II, Verhelst (2019), Wynn and Fougere 2007. Brendieck-Worm and Melzer (2018)
Parsley (*petroselinum crispum)*	Herb, seed, root	Essential oil: apiol, myristicin, alpha- and beta-pinene, beta-phellandrene, eugenol, 1-allyl-2,3,4,5-tetramethoxybenzene, flavonoids: apiine, luteoline; furanocoumarins: bergapten, xanthotoxin, psoralene, imperatorin	Emmenagogue, spasmolytic, galactagogue, carminative, expectorant, anti-histaminic, diuretic, cytoprotective, cardioprotective, hepatoprotective, nephroprotective, neuroprotective, anti-diabetic, spasmolytic, diuretic, antibacterial antifungal	Dyspepsia, colic, flatulence, oedema, anorexia	Liber herbarum II, Verhelst (2019)
Red Clover (*Trifolium pratense*)	Herb with flowers	1-Octen-3-Ol, 2-Phenylethan-1-Ol, 6-Alpha-Hydroxy-medicarpin, Biochanin A, Biochanin-A-7-O-Beta-D-Glucoside-6-Malonate, Calycosin, daidzin, ormononetin-7-O-Beta-D-Glucoside-6-Malonate, genistin, Genistin-6-O-Malonate, Pratensein, Trifolirhizin, Tannic acid, Genistein, glycoside, Isorhamnetin, coumarin, essential oil, vitamin C, B1-3	Cholagogue, depurative, estrogenic, anti-oxidant, antitrombotic, diuretic, expectorans, sedative, inti-inflammatory	Bronchitis, cough, liver support, kidney support, lack of estrogens	Liber herbarum II, Verhelst (2019),
Salad burnet (*Sanguisorba minor)*	Herb	Gallic acid, tanning agents, tannic acids, tannin, vit. C	Anti-hemorrhagic, diuretic, adstringent,	Indigestion, diarrhea	Liber herbarum II
Shepherd's-purse (*Capsella bursa-pastoris*)	Herb	Tannin, diosmine, rutin, rutenoside, quercitin, cholin, Flavonoid, vitamin A, B1 and 2, C, oxalic acid	Antihemorrhagic, Metrorrhagia, Modulating blood pressure, diuretic, adstringent, anti-inflammatory	Oedema, constipation, diarrhea, bleeding wounds, after partus	Liber herbarum II, Verhelst (2019)

Name	Part used	Constituents	Biological action	Indication	References
Sheep sorrel (*Rumex acetosella*)	Leaf, root	Catechin-Tannin, Adenosine, anthraquinone, Auxin, calcium oxalate, Chrysophanic acid, tannin, hyperoside, coumarin, rutin, tartaric acid, oxalic acid	Diuretic, adstringent	Diarrhea	Liber herbarum II
Soft rush (*Juncus effusus L.*)	Herb, root	2-Tridecanone, Xylan, zinc, Beta-Sitosteryl-Beta-D-Glucoside, Beta-Sitosterol, Hexahydrofarnesyl-Acetone, pentosan, minerals	Depurative, diuretic, toxic	Root used in traditional Chinese Medicine	Liber herbarum II
Stinging nettle (*Urtica dioica*)	Leaf, whole plant, seed, root	Flavonoids, rutin, astragalin, caffeic acid, coumarin, phenolic acids, sterols, minerals, vitamin A and C.	Anti-inflammatory, diuretic, nutritive, hemostatic, antidiarrheal, support kidney, arthritis, allergic rhinitis, immune modulation, Hepatoprotective, Nephroprotective, neuroprotective	Blood purifying, diuretic, inflammation, Tonic, digestive, liver and kidney support, arthritis	Wynn and Fougere 2007. Brendieck-Worm and Melzer (2018). Verhelst, G. (2019). Humphries and Reynolds, (2014). Joshi et al. (2015). Salih, N.A. (2015).
Tall buttercup (*Ranunculus acris)*	Herb	Vitamin C, poisonous glycosidic-bound anemonol, saponin, Flavoxanthin, protoanemonin, anemonin, flemiphilippinin c	Antispasmodic and analgetic properties, anemolol causes itch, rashes or blistering, nausea	None	Liber herbarum II
Thistle (*Cirsium spp.*) *Arvense* (vulgare)	Herb	Acaciin, rutin, Protocatechu-aldehyde, betasitosterol, Tanning agents, Pectolinarin, mucilage	Amenorrhoea, appetite, cholagogue, emetic, diuretic, anti-inflammatory, hepatic, adstringent,	Anorexia, herbal tonic, bleeding disorders, diarrhea,	Liber herbarum II, used in TCM
White clover (*Trifolium repens*)	Herb with flowers	Tannic acid, coumestrol, essential oil	Gout, tonicum	Gout, tonicum	Liber herbarum II
Yarrow (*Achillea millefolium L.)*	Herb, flowers	Essential oils, chamazulene, cineol, campher, flavonoids, apigenin, luteolin, hydroxycoumarin, chlorogenic acids (polyine alkamide, betaine), rutine, quercitine, achileine, stachydrine	Antiphlogistic, spasmolytic, choleretic, antimicrobial, anti-hemorrhagic, adstringent	Anorexia, indigestion, wounds, dermal infections	Liber herbarum II Brendieck-Worm and Melzer (2018)

Table 2 *The following plants as mentioned in Table 1 were examined for effects on health and literature on effects on heat stress.*

English name	Botanical name	Resilience	Heat stress
Alfalfa	*Medicago sativa*	positive	none
Black medick	*Medicago lupulina*	positive	none
Birdsfoot trefoil	*Lotus corniculatus L.*	positive (in small quantities)	none
Bitter dock	*Rumex obtusifolius*	negative/ positive	none
Caraway	*Carum carvi L.*	positive	positive
Chamomile	*Matricaria chamomilla A*	positive	positive
Chicory	*Cichorium intybus L.*	positive	positive
Common chickweed	*Stellaria media*	positive	positive
Common dandelion	*Taraxacum officinale*	positive	None
Common Plantain	*Plantago major* L. and *plantago lanceolata*	positive	positive
Common sainfoin	*Onobrychis viciifolia Scop.*	positive	none
Corn chamomile	*Anthemis arvensis L.*	positive	none
Cow parsley	*Anthriscus sylvestris*	positive	none
Cuckoo flower	*Cardamine pratensis*	positive	none
Daisy	*Bellis perennis*	positive	positive
Dill	*Anethum graveolens L.*	positive	positive
Fennel	*Foeniculum vulgare Mill.*	positive	positive
Fenugreek	*Trigonella foenum-graecum L.*	positive	positive
Forget Me Not	*Myosotis spp. (arvensis, scorpiodes)*	positive	none
Hedge bedstraw	*Galium Mollugo*	positive	none
Lady's bedstraw	*Galium verum L.*	positive	none
London rocket	*Sisymbrium irio L*	positive	positive
Milk thistle	*Silybum marianum*	positive	positive
Parsley	*Petroselinum crispum*	positive	positive
Salad burnet	*Sanguisorba minor*	positive	positive
Sheep sorrel	*Rumex acetosella*	positive	none
Shepherd's-purse	*Capsella bursa-pastoris*	positive	positive
Soft-brome	*Bromus hordeaceus L.*	neutral	none
Stinging nettle	*Urtica dioica*	positive	none
Tall buttercup	*Ranunculus acris*	negative	None
Thistle	*Cirsium spp. (arvense, vulgare)*	none	none
Red Clover	*Trifolium pratense*	positive	none
White clover	*Trifolium repens*	positive	none
Yarrow	*Achillea millefolium L.*	positive	none

4 Discussion

4.1 Plants contributing to health and resilience

In the tables above many plants are mentioned which can have a possible effect on cow health and resilience. For specific plants more data were available in literature. Research comparing a herbal extract with seven herbs including *Taraxacum officinale*, sodium propionate, or placebo in cows with subclinical ketosis showed that both the herbal extract and sodium propionate, both given twice a day for five days improved subclinical ketosis (Durrer et al., 2020). In a mouse mastitis model aqueous extract of dandelion leaf showed both *in vitro* and *in vivo* anti-inflammatory action (Hu et al., 2017). As compared to other herbs (*Alchemilla vulgaris, Achillea millefolium, Plantago lanceolata, P. major, Rumex obtusifolius* and *Ranunculus acris*) dandelion (*Taraxacum officinale)* showed the highest nutritious value (Vondrášková et al., 2012). Another interesting finding was that the aqueous extract of dandelion leaves upregulated the expression of Th1 cytokines, IL-2, IFN-gamma and IL-12, and regularized the increased expression of IL- 10 in chronically stressed mice (Kour et al., 2016). The extract normalized the elevated corticosterone levels, the chronic stress-induced hypertrophy of adrenal glands and atrophy of spleen and thymus were reversed. The results show that TO-10 is also able to maintain immune homeostasis in normal and immune-compromised conditions. Whether the same effect is obtained in cattle is currently not known. In an experiment in rats the phenolic fraction of dandelion leaves showed *in vivo* beneficial antioxidant effects and changed the lipid fraction profile in a positive way (Majewski et al., 2020).

Stinging nettle (*Urtica dioica*) in cattle feed containing 50 (N5) and 100 (N10) g nettle haylage (DM/kg) as a replacement for ryegrass silage (*Lolium perenne*) led to changes in rumen pH suggesting potential benefits for reducing rumen acidosis (Humphries and Reynolds, 2014). In a feeding trial with crossbred heifers supplementation of a mixture of *Bacopa monnieri, Eclipta alba* and *Urtica dioica* herbs as a feed additive led to improvement of the utilization of nutrients and growth (Gupta et al., 2005). *Urtica dioica* seed extract is also mentioned as one of the plants that may work against aflatoxin induced toxicity due to its anti-oxidant and liver protecting action (Umaya et al., 2021). In rats challenged with CCl4 to induce liver damage, extract of *Urtica dioica* showed hepatoprotective and anti-oxidant action (Joshi et al., 2015). In rabbits oral stinging nettle ethanolic extracts protected against gentamycin induced nephrotoxicity (Salih, N.A., 2015).

Capsella bursa-pastoris is mentioned as wound healing plant used in ethnoveterinary practice for cattle (Lans et al., 2007). Recently a book chapter was devoted to the health effects of chamomile *Matricaria chamomilla* on digestive physiology, animal health and performance parameters in livestock (Demirtas, A., 2021). In another study, a mix of four plants (wormwood, chamomile, fumitory and mallow) was studied for their effect on ruminal digestion. It appeared that the medicinal plant mix had the potential to reduce methane emission and ammonia concentration, possessed strong ruminal antioxidant capacity and had a positive effect in the gastrointestinal ecosystem (Petric et al., 2020). Koc et al. 2015 found anti-oxidant activity in Cirsium Arvense. But most farmers will regard thistles as undesirable weeds (Pywell et al., 2010). Cattle were supplemented with Silybum marianum 20 g/head/day in the last three weeks of pregnancy (10 cows) or three weeks postpartum (10 cows), another group of 10 cows served as control group (Ulger et al., 2017). Treatment with silymarin significantly increased milk yield, but decreased milk protein. In the silymarin groups postpartum bodyweight loss was significantly less than in the control group. They also observed that silymarin speeded up the metabolic adaptation process of the dairy cows after the partus. In another trial (Vojtísek et al., 1991) ketotic cows treated with an extract of silymarin seed showed increased milk production and an remarkable drop in ketonuria. Research in mice with Bellis perennis L aqueous extract (BP) showed its hematoprotective and nephroprotective activities in CCl4-induced nephrotoxicity (Zangeneh et al., 2018). Stellaria Media is traditionally used as feed for poultry to increase egg production and as fodder for lambs (Guarrera et al., 2005). Cows parsely (anthriscus sylvestris) has shown to have anti-inflammatory activities (Velescu et al., 2017), but is mostly seen as an invasive weed. Sanguisorba minor is mentioned as a promising plant for methane reduction in dairy (Loza et al., 2021), gaining up to 33% reduction. Also reduction of ruminal ammonia production in cattle is described for this herb when fed to cattle (Kapp-Bitter

et al., 2021). Other herbs with a similar effect were Galium verum L., Leontodon hispidus L., Lotus corniculatus L., Onobrychis viciifolia Scop., Plantago lanceolata L. (Kapp-Bitter et al., 2021). Yarrow Achillea millifolium is known for its wound healing properties and a study in rabbits (Jalali et al., 2012) confirmed that an extract of yarrow improved the quality of healing of burn wounds and reduced the amount of pathogens in these wounds. Moreover Yarrow also proved effective against intestinal nematodes in sheep, both *in vitro* and *in vivo* (Tarq et al., 2008). Fennel (Foeniculum vulgare) seeds fed to Holstein calves from three days of age in the milk and from 31 days as topdressing over the feed showed to improve growth and bodyweight and reduced the number of days with pneumonia and diarrhea as compared to untreated controls (Nowroozinia et al., 2022). In Egyptian buffaloes postpartum feeding of fennel 75 gram/day significantly improved feed efficiency, milk production and milk quality (fat concentration and milk energy content), and it decreased the somatic cell count (P=0.035) compared with the controls (Fahim et al., 2021). In lambs feeding fennel seeds improved ruminal fermentation and meat quality (Hajalizadeh et al., 2020).

Sainfoin (*Onobrychis viciifolia*) fed to cattle showed to improve protein digestibility and reduced greenhouse gas emissions (Wijekoon et al., 2021). Anthelmintic effects of sainfoin in small ruminants are well documented, but data in cattle are scarce. *In vitro* research with tannin rich plants like *Onobrychis viciifolia*, *Lotus pedunculatus* and *Lotus corniculatus* indicated that tannin-containing plants could act against cattle nematodes (Novobilský et al., 2011). In a feeding experiment calves (2-4 months of age) were fed a concentrate and grass-clover hay diet, or an isoproteic and isoenergetic diet consisting mainly of sainfoin pellets and after 16 days experimentally the animals were infected with nematodes (*O. ostertagi and C. oncophora)*. At 42 days after infection the calves were euthanized and investigated for worm burden in the digestive tract. In the Sainfoin group the number of *O. ostertagi* adults in the abomasum was reduced by 50%, but the total worm burdens of *C. oncophora* was found similar between the groups (Desreus et al., 2016). Moreover the growth was less in the Sainfoin group. Other studies showed that sainfoin improved protein utilization and can be used as a bloat-free forage with anthelmintic characteristics (Wang et al., 2015). Birdsfoot trefoil (*Lotus corniculatus*) mixed pastures with nutritious grasses increased herbage intake by grazing Jersey heifers (Rose et al., 2021). It is extensively tested as a bloat-free tannin rich forage crop which also showed to reduce methane production (Christensen et al., 2017). Dill (*Anethum graveolens L.*) is mentioned as one of the plants with essential oil that *in vitro* reduced methane production with 20-30%, together with lavender and holy basil (Tekippe et al., 2012). Lans et al., 2007 report dill as one of the plants used in ethnoveterinary medicine against diarrhoea. Caraway (*Carum Carvi L.*) is mentioned as a plant that can improve mineral composition of grasslands (Pirhofer-Walzl et al., 2011). *In vitro* research for anthelmintic activity of alcoholic extracts from a wide range of herbs showed caraway as one of the most promising candidates (Urban et al., 2008). Garlic (*A. sativum*)*,* wormwood (*A. absinthium*)*,* caraway (*C. carvi*)*,* forking larkspur *(C. regalis*)*, Elecampane (I. helenium),* English walnut (*J. regia*)*,* Summer savory (*S. hortensis*)*,* and common vervain (*V. officinalis*) showed an even better effect than albendazole against the infective third-stage larvae of *Ascaris suum* and infectious larvae *Trichostrongylus colubriformis*. In an *in vitro* assay caraway also showed a slight ruminal ammonia reducing effect (Hristov et al., 2008). In an experiment with fish exposed to a sublethal dose of an organophosphorus insecticide (bifenthrin) they found neuroprotective, antioxidant, genoprotective, anti-inflammatory and antiapoptotic effects of the essential oil of parsley (*Petroselinum crispum*) (Farag et al., 2021). Parsley is also used as ethnoveterinary treatment for stomach problems (Lans et al., 2007). Alfalfa (*Medicago sativa*) is known as a nutritious feed, and a trial in goats showed also some anthelmintic activity when goats where finished on an alfalfa rich pasture. These animals where less affected by gastrointestinal nematodes (Turner et al., 2013). Fenugreek (*Trigonella foenum-graecum L.*) is mentioned for its methane reducing properties due to its saponin contents (Niu et al., 2021). In a review of promising plants (Wijekoon et al., 2021) fenugreek is regarded as a bloat-free forage legume with a high protein content and other health promoting ingredients such as crude fiber, 4-hydroxyisoleucine, steroid sapogenins and galactomannans. Fenugreek seeds also showed hepatoprotective properties in rats exposed to the environmental contaminant AlCl3 (Belaïd-Nouira et al., 2013). Insecticidal effects of the oil of fenugreek was demonstrated against blowfly (*Lucilia sericata*) larval stages (Khater and Kather, 2009). Whether the plants in practice will exert the effects mentioned in literature depends on the availability in the pasture and the amount of plant material that the animals eat.

4.2 Plants affecting heat stress

Heat stress reducing plants are mentioned in a recent review (Abd El-Hack et al., 2020). Grassland plants mentioned include dill, chicory and fennel. Ramadan et al. (2010) mentioned London rocket *(Sisymbrium irio* L) which is a kind of Brassicaceae endogenous to the Netherlands. In a study the inclusion of London Rocket (*Sisymbrium irio L*), Psyllium (*Plantago Psyllium*) and white wormwood (*Artemisia herba-alba*) mixed into the feed was evaluated for their effects on heat stress in Awassi sheep. During three weeks, 20 ewes were allotted to four experimental groups. One group served as a control and the three other groups received one of the medicinal herbs. Treatment of the ewes showed a significant ($p < 0.05$) reduction in respiration rate, rectal temperature, and a trend to increase water consumption for the London rocket group. The authors concluded that London rocket in the diet could reduce heat stress. Chicory (*Cichorium intybus L*) extract and vitamin C in broilers under heat stress showed to improve liver and kidney activity and fat metabolism (Khodadadi et al., 2016). For grazing cattle the use of trees and shrubs providing shadow is an effective way to reduce heat stress.

Recently more research has been performed on the possibilities of herbs supplemented to the feed to reduce heat stress in livestock. Supplementing a herbal mixture to sheep during heat stress improved feed intake, enhanced serum and liver antioxidant status, and improved growth performance in lambs (Hashemzadeh et al., 2022). The herbal mixture consisted of 50% rosemary leaves (*Rosemarinus officinalis*), 20% cinnamon barks (*Cinnamomum zeylanicum*), 20% turmeric roots (Curcuma longa), and 10% clove buds (*Eugenia caryophyllata Thunb*.) which was added at a concentration of 1 or 2% to the diet. A research group from Greece found that dietary supplementation of dairy ewes with cornus (*Cornus officinalis*) extract in combination with oregano and thyme essential oil could improve feed utilization and the production under heat stress (Kalaitsidis et al., 2021). In China experiments were performed with Japanese honeysuckle (*Lonicera japonica*) extract (LJE) in heat-stressed mid-lactation dairy cows (Ma et al., 2020). They evaluated lactation performance, antioxidant status, and endocrine and immune function in these animals. With supplementation of 28 g/d LJE, the animals were able to cope with heat stress by improving antioxidant status and promoting endocrine and immune functions. Supplementation of calves with rosemary (*Rosemarinus officinalis*) leaves also improved growth and performance during heat stress (El-Masry et al., 2018). Investigation in dairy goats fed fenugreek (*Trigonella foenum-graecum L*.) seeds showed positive effects on milk yield, physiological and haematological parameters, and antioxidant capacity during heat stress (El-Tarabany et al., 2018). Most research on heat stress with herbal products is done in poultry (data not shown). Whether the plants in practice will exert the effects mentioned in literature depends on the availability in the pasture and the amount of plant material that the animals will eat. More research is needed for this, but the abovementioned promising results ask for further research under Dutch conditions.

Conclusions

- Many grassland herbs can exert positive effects on animal health and resilience
- Research showing health effects of biodiverse pastures is scarce
- Some plants can affect the ability of animals to cope with heat stress
- Best results were obtained with plant(extracts) added to the feed

Recommendations

- Research on effects of specific combinations of herbs in herbal grassland on cow health under Dutch circumstances
- Research on the effects of plants added to the feed on heat stress under Dutch circumstances

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